VOLUME XVIII NUMBER 3 WHOLE NUMBER 137

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.
SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(*Ten numbers per year*)

March, 1924

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

FOREIGN AGENTS: WHELDON & WESLEY LTD.
2-4 ARTHUR STREET, NEW OXFORD STREET, LONDON, W.C. 2

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XVIII, No. 3 MARCH, 1924 WHOLE No. 137

Articles PAGE

A Review of Astronomy during 1923 - - *W. E. W. Jackson* 73

Annual General Meeting (Minutes) - - - - - - - - - 82

The Sproul Observatory Expedition to Observe the Eclipse of the Sun, September 10, 1923 *John A. Miller and Ross W. Marriott* 95

The Winter Sky - - - - - - - - - *A. Vibert Douglas* 102

Recent Progress in our Knowledge of the Universe *Robert G. Aitken* 106

Review of Publications - - - - - - - - - - - 122

Notes and Queries - - - - - - - - - - - - 124

Meetings of the Society - - - - - - - - - - - 130

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

PLATE III

EAST LIMB

THE SOLAR CORONA, September 10, 1923

Photographed with the lens of 15 foot focal length at Yerbanis, Mexico, by the Sproul Observatory Expedition.
Exposure 55 sec. Size 86/100 of original.

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XVIII MARCH No. 3

A REVIEW OF ASTRONOMY DURING 1923

By W. E. W. JACKSON

(Retiring President's Address)

THE subject of my address this evening is "A Review of Astronomy during 1923". It is not my intention, however, to speak of all the accomplishments of the year which have been of interest to the astronomer, as the time at my disposal would prevent the completion of such a task, but of a few which have made more real to us, through the observations and investigations, the ever passing wonders of the universe of which we form so infinitesimal a part.

Progress in science does not always consist of what is learned. Very often it means unlearning some of the theories which had been accepted as established, but which new information has proven to have been formulated on an insufficient basis, or perhaps on only partial truths. Early in the year Dr. Chant was able to announce that the reduction and computations of the results of the Canadian Expedition to Australia to view the eclipse of the sun on September 21, 1922, were completed and that they were in favour of the prediction made by Einstein that light rays in passing the sun would be deviated from their path and that the deviation would amount to 1".74 at the sun's limb.

Following shortly after Dr. Chant's announcement of this result came confirmation from Dr. Campbell of the Lick Observatory. Their results were also in favour of the Einstein prediction, again confirming the results obtained by the two English expeditions of 1919, results of which had been questioned by many prominent astronomers.

It was hoped that the eclipse of September 10, 1923, would have provided additional observations to test this same prediction, as it is undoubtedly desirable to repeat the observations at several future eclipses, but weather conditions proved unfavourable. The star field for this eclipse, the path of which crossed this continent over Mexico, was not a very good one, and any results obtained have not yet been published.

The next eclipse, which takes place on January 24, 1925, will have a better star field as there will be eight stars brighter than the eighth magnitude within two degrees of the sun. This eclipse will also be of more particular interest locally as Toronto lies on the northern limit of the path of totality. A short trip to the Niagara peninsula will insure one of being well within the path of the total phase. The low altitude of the sun, the eclipse here will be shortly after sunrise, the short duration of totality, about 90 seconds, and normal winter conditions are likely to prevent the securing of observations which may confirm or confuse our ideas which have been developed by the Einstein theory.

The first test predicted by Einstein was the movement of the perihelion of Mercury's orbit, and his theory was found to meet the situation with such exactitude that it was generally accepted as proven in this particular. Various attempts have been made to account for this motion by assuming that asteroidal matter or that matter which caused the zodiacal light might be sufficient to account for this motion, but these theories have not been considered satisfactory.

The third prediction, that spectral lines are displaced toward the red end of the spectrum, has lately been confirmed by the work of Professor St. John, of Mt. Wilson Observatory. At the fall meeting of the American Association for the Advancement of Science held at Los Angeles, Professor St. John announced that "as a result of his measurements he calculated that the displace-

ment of the lines in the solar spectrum predicted by Einstein amount to 86% of the total observed effect, the remainder being due to other well-known effects resulting from conditions in the solar and terrestrial atmospheres and to the sun's rotation on its axis; and he considers as proved the main prediction of Einstein that in the vicinity of the centre of the gravitational field of the sun the rate of vibration of atoms is slowed up as compared with their rate when as far from the sun as is the earth."

It can now hardly be denied that the three predictions, which Einstein derived from his general theory of relativity, have been fairly well confirmed.

A solar eclipse provides also the means whereby we may make a more minute study of the constitution of the sun. From the sun we obtain spectra of three different types—the Fraunhofer, the sun spot and the flash or chromosphere spectrum. The first is of stellar type G0, the sun-spot of later type about K0 and the flash of earlier type represented by F0.

The Fraunhofer spectrum of dark lines on a bright background persist during the partial phase of an eclipse until almost the beginning of the total phase when the high level lines begin to appear gradually extending out beyond the dark line spectrum. At the moment of totality the dark line spectrum disappears and is replaced by the spectrum of bright lines on a dark background, every spectrum line being apparently reversed. It is possible to obtain the flash spectrum without waiting for an eclipse, but the greatest success is attained at the time of a total eclipse.

If such reversal of the spectrum lines were exact as regards wave lengths and intensities we would gain little additional knowledge of solar physics. The variations from the ordinary spectrum make it both interesting and important. If the flash spectrum is photographed without a slit the length of arc of the spectrum lines provides the means whereby we may determine the heights to which each vapour extends above the photosphere. "Enhanced" lines are particularly prominent in the chromosphere and the vapours producing these lines extend to much greater altitudes than do ordinary ones. Saha's theory of ionization shows that at the reduced pressures consequent on these high altitudes the atoms may be ionized or, in other words, may have an excess

charge of positive electricity. The atom so ionized gives an enhanced line in the spectrum, and we are thus able to account for the greater heights at which calcium of atomic weight 39 is found than the much lighter gas hydrogen. The H and K lines of calcium have their origin in the ionized atom, whilst the hydrogen lines belong to the neutral atom.

Some other interesting facts in regard to our own fixed star have recently been announced by Professor Hale. At the time of minimum spot activity 11 years ago he found evidence of a reversal of polarity of the spots, but, being in doubt lest a mistake had been made, the observations have been repeated during the present minimum period with confirmatory results. "There is now", he says, "no doubt that throughout one cycle the magnetic polarity of the leading spot in bi-polar groups is opposite to the polarity during preceding and following cycles." Are we now to consider the sunspot period as being 22 or 23 years in length instead of a little over 11, as has been generally accepted?

Other matters of interest in sunspot results for 1923 may be briefly summarized. The decline in activity has apparently reached its limit. The groups observed in November and December of 1923 were in high latitudes and would appear therefore to mark the beginning of a new spot cycle, and we may now look for an increase both in number and size of spotted areas. The relative number for 1922, computed from results of observations on 149 days, made at the Toronto Observatory on Bloor Street, and based on the Wolfer formula, was 17 and that for 1923, from 137 days, was only 9.

Before leaving the solar system let me remind the amateur astronomer of how he can make his astronomical observations of value. If he is equipped with a telescope he will find that he can be of great service in checking the variations in the moon's motion by accurately timing the occultations which take place within two or three months of an eclipse. He may also find his services of use in establishing the positions of radiant points in meteor swarms. Motion of the radiant of the Orionids was suggested by Professor Olivier of Leander McCormick Observatory, and he claims this motion has been confirmed by measures of trails obtained on photographic plates by Professor King and published in Harvard

College Bulletin 778. Denning and other British observers contest this statement and maintain that the radiant points are stationary and they submit very strong arguments for their views. The Orionids 91°, +16° and the Geminids 99°, +13° are often confused as their periods overlap. Both are often active together in October and sometimes in September. They also point out that there are many subsidiary swarms whose orbits are not very different from those of the Orionids. The observation of meteor radiants is not a difficult observation for the amateur, and will also assist him in becoming familiar with the stars and their position in the sky.

Let us now for a few minutes allow our minds to carry us in imagination out far beyond the limits of the solar system, to regions where distances have to be expressed in units which seem almost infinitely large to our finite minds, and scan the developments during the past year.

The determination of stellar magnitudes, photovisual and spectroscopic, and proper motions has been proceeding according to the Kapteyn proposal of 1906 and the third progress report by Professor Rhijn of Groningen, 1923, has appeared. A recapitulation of the work done for the northern areas has been published by Harvard Observatory and a similar work for southern areas on plates taken at Arequipa is in the press. About a quarter million stars to the 16th magnitude are included.

The extension of work with the interferometer has opened up a new realm for exploration and already we have results which have been startling to the astronomer and layman alike. The almost inconceivable diameter of Betelgeuse, of 218 million miles, has been far surpassed by the fiery red star in the heart of the Scorpion, known astronomically as α Scorpii and popularly as Antares, whose diameter is not less than 280,000,000 miles and may be as great as 430,000,000 miles.

The old nursery rhyme, "Twinkle, twinkle *little* star", will need to be revised to accord with modern ideas of stellar bodies.

Ancient astronomers called Antares the "Rival of Mars" because when Mars is in that portion of its orbit more distant from the earth it closely resembles in colour and brightness this super giant of the universe. How astounded they would be to learn that this star which they believed to be a rival of a planet of

our system was so large, that it would more than fill the entire orbit of Mars, and our own earth would be lost millions of miles beneath its surface.

Scarcely less remarkable have been the great advances in radiometry, that is, in the quantitative measurement of total radiation from the stars. This work has been developed specially by Coblentz, whose delicate stellar thermocouple is from 150 to 200 times as sensitive as Nichols' stellar radiometer by means of which radiation was first detected from Arcturus at the Yerkes Observatory in 1900. The quantitative results for considerably more than 100 stars to the fourth magnitude have already been issued. Using these results Stetson in *Popular Astronomy*, April, 1923, has developed a formula which connects the diameter of the star with its radiometric measures and thus gives an independent method of obtaining the order of magnitude of stellar diameters. His formula expressed in convenient form for computation is $D''=0.00092\ (6000/T)^2\sqrt{d}$ where D is the diameter of the star sought and T is the temperature obtained from the well-known curve relating spectral type and star temperature, based on an absolute solar temperature of 6000°, and d is the galvanometer deflection in mm.

Using this formula the following table of computed apparent diameters was made:—

	Type	Parallax ″	Approx. diameter ″	In miles
α Orionis	Ma	0.018	0.047	242,000,000
α Scorpii	Map	0.009	0.037	382,000,000
α Herculis	Mp	0.015	0.030	185,800,000
β Pegasi	Mb	0.035	0.028	74,400,000
α Tauri	K5	0.062	0.021	32,000,000
α Boötis	K0	0.095	0.017	17,000,000
β Geminorum	K	0.06	0.009	14,000,000
α Aurigae	G	0.078	0.007	8,360,000
γ Andromedae	Kp	0.004	0.007	163,000,000
α Canis Majoris	A0	0.367	0.004	1,030,000
α Persei	F5	0.02	0.002	9,000,000
α Leonis	B8	0.03	0.001	3,000,000

The agreement in values thus obtained with those of the few stars so far obtained by the interferometer method is remarkable.

Work on the nebulae has not been neglected, whilst these other startling revelations were being made. Dr. Hubble of Mt. Wilson has recently presented a paper, in Mount Wilson Contribution No. 241, on "A General Study of the Diffuse Galactic Nebulae", based on his extensive study of nebulae through the past few years. He suggests a classification of nebulae, first of all into galactic and non-galactic, and subdivides these into planetaries and diffuse nebulae belonging to the galactic, and spiral, elongated, globular and irregular to the non-galactic. His investigation of diffuse nebulae has produced some striking results. He finds that stars involved in nebulae having continuous spectra and presumably shining by reflected light are nearly always of spectral type B, or later, whilst stars involved in nebulae with emission spectra are always of earlier type than B. He states: "This intimate relation between spectral type of nebula and involved stars raises a presumption that one is a consequence of the other. It seems more reasonable to place the active agency in the relatively dense and hot stars than in the nebulosity."

The emission nebulae are apparently excited to luminosity by radiation from the very hottest stars and as the cooler stars are incapable of doing this, the nebulous matter surrounding them shines only by reflected light.

Every diffuse nebulosity is near enough to a bright star, or group of stars, to be under stellar influence, and its luminosity is not necessarily a property of the nebula itself. This suggests that the normal nebula is dark, and the bright nebula a special case. Thus in the case of the Orion nebula, whose spectrum suggested to Sir Wm. Huggins that it was related to involved stars, is claimed by Russell "to be selectively sensitive to the incident excitation and gives out most of the light just as gases do in the coma or tail of a comet, and that the luminous gas does not form the whole or even a large part of the matter present".

Russell accounts for the origin of these dark clouds in radiation pressure. Dwarf stars are incapable of repelling dust particles, but the giant B stars do repel such particles very powerfully; and he suggests that this fact may explain why the luminous

portions of these nebulae do not brighten up in the immediate neighbourhood of the involved star. This repelled dust is finally driven out of the galactic system to form non-galactic nebulae with their high velocities of recession.

Professor Lindemann has also advanced an interesting theory in regard to the constitution of the spiral nebulae. The old view that they are composed of a multitude of stars similar to our own galactic system and form "island universes" will explain their spectrum and is not in disagreement with their shape or with the appearance of novae in them from time to time, but does not explain the very high receding velocities, nor why they in general avoid the plane of the galaxy, nor why the centre is redder than the edges. Lindemann suggests that they consist of dust particles whose diameters are of the order 10^{-4} cm. and are expelled from bodies like the sun by light pressure and the effect of repulsion by all stars causes them to accumulate in regions of low radiation density. Such clouds of dust collecting in these regions will be unstable and sooner or later be expelled from the galaxy. As light pressure may exceed gravity many times, the high receding velocities are easily accounted for. The light of the spectra by this hypothesis must be admitted to be the reflected light from the stars and their spectra is that of the average galactic stars. An explanation is also obtained of the reddish centres. As by hypothesis the dust particles are repelled by light pressure, and it is evident that gravitational attraction will have greater effect on larger particles than smaller ones and therefore the larger will congregate more in the centre, and as the smaller reflect blue light better than red the centre has a reddish appearance. His greatest difficulty was in the appearance of novae, which he could only account for by assuming comet-like clouds of stones passing through the nebulae, which, by collision with the dust particles, are heated until vaporized, when the space would rapidly fill with gas and this gas would continue in motion until brought to rest by collision with nebular particles, generating in the process a large amount of energy. The mass of the nebula, assuming what he considered to be probable average values, would seem to be less than 10^{37} grams, or some thousand times the sun mass.

There are one or two other interesting things I want to mention

before closing. The variable star Omicron Ceti (Mira) is still baffling astronomers. Its discovery as a variable was made by Fabricius in 1596. Later it was found to vary from about second magnitude at maximum to about ninth magnitude at minimum in a period of about eleven months or 330 days. Its spectrum indicated it was of class M, which means a red star. In contrast with the majority of red stars, however, Mira shows bright lines due to hydrogen. Examination of the spectrum by Dr. Joy of Mt. Wilson led him to announce about a year ago that the spectrum had a certain peculiar aspect which was only associated with blue stars and he concluded that it might be due to a faint blue companion or at least one in the line of sight, and computed its distance at about 0″.3 and position angle 135°. A search for this companion at the Yerkes Observatory revealed nothing, but recently Dr. Aitken of the Lick Observatory announced that he had discovered a tiny blue star 1″.01 distant from the variable and in position angle 132° and about one or one and a half magnitudes fainter.

The other interesting fact is that RZ Cephei (223564) has been reported from Harvard as having the highest velocity yet found for any star, namely, 1100 km. per sec. It is a faint cluster variable with a light curve of the usual cepheid type, and is about 3800 light years distant.

In closing, let me read you that beautiful little poem of Charles Nevers Holmes on "Man", which I think is particularly appropriate:

> Man, chained to earth, surveys the firmament,
> And, freed by mind, unshackled visits Mars,
> Or swiftly soars from Neptune's wide extent
> To constellations, set with sparkling stars.
>
> Imprisoned by a world, a world without,
> Man pondered o'er its problems from within,
> Until, released from ignorance and doubt,
> He knew that where Earth ends, there worlds begin.
>
> Amidst the cells that form our finite minds,
> He measures from the centre of his Earth
> Abysmal depths, abysmal heights, and finds
> His mind is free, despite its body's berth.
>
> Man, who has sprung from instincts of Earth's sod
> Shall break his chains, and closer worship God.

ANNUAL GENERAL MEETING

THE Annual General Meeting of the Society was held in the Physics Building of the University of Toronto, at 8 p.m., January 15, 1924, the President, Mr. W. E. W. Jackson, in the chair.

On motion, the minutes of the last annual meeting, as printed in the JOURNAL, were approved.

Miss E. M. Budd and Mr. L. B. Leppard were appointed scrutineers to count the ballots cast for the election of the officers for 1924.

The General Secretary presented and read his report for 1923, which included the reports of the various centres, five in all, and on his motion, seconded by Dr. Fraser, it was received and adopted.

The General Treasurer's report of the receipts and expenditures for 1923, including the statement of the Building Fund, was presented and read, and on motion was received and adopted.

The best method of showing the general assets of the Society, including instruments, library, etc., was discussed by Dr. Fraser, Mr. Miller and Prof. Chant, and an estimate from the curator for the next Council Meeting was requested. The registration of the bonds held was approved and requested.

The Librarian presented and read his report for 1923, and on his motion, seconded by A. F. Hunter, it was received and adopted.

The scrutineers reported that the following officers for 1924 had been elected:—

Honorary President: Hon. G. H. Ferguson, K.C., B.A., LL.D., Minister of Education for Ontario, Toronto.

President: R. M. Stewart, M.A., Ottawa.

First Vice-President: Wm. Bruce, J.P., Hamilton.

Second Vice-President: A. F. Hunter, M.A., Toronto.

General Secretary: F. T. Stanford, Toronto.
General Treasurer: H. W. Barker, Toronto.
Recorder: H. F. Balmer, B.A.
Librarian: Prof. C. A. Chant.
Curator: Robert S. Duncan.

Council: Mgr. C. P. Choquette, M.A., Lic. Scs., Montreal; J. B. Fraser, M.D., Toronto; R. A. Gray, B.A., Toronto; A. R. Hassard, B.C.L., Toronto; J. H. Horning, M.A., Toronto; Prof. John Matheson, M.A., Kingston; Sir Joseph Pope, K.C.M.G., Ottawa; John Satterly, M.A., D.Sc., Toronto; Dr. W. M. Wunder, Toronto.

The chairman declared the above officers elected for the year 1924 and requested Mr. A. F. Hunter, the Second Vice-President elect, to take the chair. He did so, and thanked the Society, on behalf of the new officers, for the measure of confidence reposed in them. The increase of their responsibilities, nevertheless, was not lost sight of, and would be faithfully undertaken for the Society so deserving of their care and attention.

On motion by Mr. Jackson, seconded by Prof. Chant, it was resolved that the auditors, Dr. J. B. Fraser and A. R. Hassard, B.C.L., and the scrutineers, Miss E. M. Budd and Mr. L. B. Leppard, receive the thanks of the Society for their services, and that the same auditors be asked to continue in their office for 1924.

On motion by Prof. Chant, seconded by Dr. Fraser, it was resolved that a committee consisting of Mr. Hunter, Mr. Jackson and Mr. Collins be appointed to prepare the programme of papers and addresses for the programme of the Spring term.

The meeting was then adjourned.

Report of the General Secretary for 1923

The membership list has been maintained at the same figures as in the preceding year 1922, viz., at 556, notwithstanding some general depressed financial conditions. The following table gives

the figures according to Centres, as shown by the Society's mailing list of January 1st, 1924:—

Centre		1922	1923
Toronto	City	111	103
	Outside	120	112
Ottawa		81	89
Hamilton		8	6
Victoria, B.C		54	66
Winnipeg		61	53
Montreal		71	81
London, Ont		50	46
		556	556

In addition to these 556 ordinary members, there are 24 paying subscribers, 14 life members and 18 honorary fellows.

There were 16 meetings held at Toronto during the year 1923 at which the following 27 papers and addresses were read or delivered:—

1923

Jan. 23. W. E. W. Jackson, M.A.—"The Work of the Society and the Progress of Astronomy during 1922."
Feb. 6. Mr. A. F. Miller—"The Structure of the Atom."
Feb. 20. A. F. Hunter, M.A.—"Planetary Laws in Atomic Forms."
Mar. 6. Mr. A. F. Miller—"Fraunhofer and his Work."
Mar. 20. Mr. Harold Bibby—"A Meteorological Trip in the Mackenzie Basin."
Apr. 3. Wilson Taylor, B.A.—"Molecular Tension in relation to Cosmic Phenomena."
Apr. 17. Prof. J. L. Synge—"Space and Time."
May 1. J. H. Horning, M.A.—"Some Examples of Practical Work of the Department of Astronomy, University of Toronto."
May 15. Rev. E. D. Robinson, M.A., B.D.—"Bermuda and its Astronomical Needs."
Mr. A. F. Miller—"Methods for Examining the Spectra of Metals."
Oct. 2. Mr. J. R. Collins—"The Constellation Cygnus."
W. E. W. Jackson, M.A.—"Magnetic State of the Earth during Solar Eclipses."
Mr. A. F. Miller—"Changes in a Helium Tube."
Oct. 16. Mr. A. F. Miller—"The Constellation Cetus."
Mr. Jas. Young—"Toronto Observatory Record of the Japan Earthquake."
A. F. Hunter, M.A.—"Volcanic Action in the Earth and the Moon."

Oct. 30. W. E. W. Jackson, M.A.—"The Constellation Pegasus."
Prof. John Satterly—"The Solar Atmosphere; including information obtained at recent eclipses."
Nov. 13. Mr. A. F. Miller—"The Constellations Cygnus, Cetus and Pegasus."
A. F. Hunter, M.A.—"The Pleiades."
John A. Paterson, M.A., K.C.—"Edward Emerson Barnard; the man, the philosopher, the astronomer."
Nov. 27. Mr. A. F. Miller—"The Pleiades."
Prof. C. A. Chant—"The Constellation Orion."
R. A. Gray, B.A.—"Early Eclipses."
Dec. 11. Mr. A. F. Miller—"The Constellation Orion."
A. R. Hassard, B.C.L.—"The Constellation Cassiopeia."
J. W. Melson, B.A.Sc.—"The Surveying Camp of the University of Toronto at Gull Lake, Victoria County."

In addition to the foregoing papers and addresses, on February 20 Miss E. M. Budd read some selections on astronomical topics from the recently published volume of poetry by Sir Arthur Noyes, called "The Torch Bearers"; and at the various meetings many contributed brief remarks on observations of astronomical phenomena or recent publications on the same; for all of which, and the many other benefits received, the retiring officers are thankful, and herewith tender their grateful acknowledgments.

Further, an Open-Air meeting with telescopes was held on May 23, and later, throughout the summer, many similar opportunities to view celestial objects through telescopes were afforded by the University Extension Department.

No fixed line of policy regarding papers and addresses had been specified or adopted, yet the entire list of 27, with the single exception of the paper by the Rev. E. D. Robinson of Bermuda, who, owing to the distance, was not present to read it, were by members living in Toronto. Nearly all were illustrated with lantern slides, which materially added to their interest. The plan of having a member describe one of the constellations visible in the night sky at the time of the meeting added several extra papers and addresses during the autumn term, as compared with former years.

The attendance at the meetings was a good average, but some difficulty is of course always found in making technical subjects interesting to the general public.

The JOURNAL during the year contained 420 pages and 24 plates, being 100 pages more than in 1922, and was abreast with former years in the value and interest of its papers and articles.

Respectfully submitted,

A. F. HUNTER,
General Secretary.

TREASURER'S STATEMENT FOR 1923

Receipts

Cash in Imperial Bank, Dec. 31/22	$ 795.71	
Grant from Dominion Government	2,000.00	
Grant from Provincial (Ontario) Government	600.00	
Grant from City of Toronto	100.00	
University of Toronto (50 Journals)	100.00	
Fees from Members	897.83	
Interest on Bank Deposits	42.58	
Sundry Receipts—Sale of Magazines	82.94	
		$4,619.06

Disbursements

Publications JOURNAL, HANDBOOK, and Printing	$2,571.33	
Public Meetings, Toronto	113.30	
Library, Books, etc	103.89	
Stationery, Stamps, etc	297.69	
Salaries (Assistant Librarian and Caretaker)	430.00	
Rent of Rooms	120.00	
Transferred to Building Account (Int. on Bonds in 1922)	110.00	
Grant to Montreal Centre	98.63	
" Ottawa Centre	111.75	
" London Centre	58.50	
" Winnipeg Centre	70.50	
" Victoria Centre	91.50	
Miscellaneous Expenses	46.54	
Balance in Bank	395.43	
		$4,619.06

Audited and found correct,

(Signed) A. R. HASSARD,
J. B. FRASER, M.D.,
Auditors.

(Signed) H. W. BARKER,
General Treasurer.

BUILDING FUND STATEMENT

Receipts

Interest on Bonds for 1922, transferred from General Account	$110.00	
Contribution from C. A. Chant	500.00	
Interest on Investments	123.75	
Interest on Bank Account	12.68	
		$746.43

Statement of Bonds held by Imperial Bank

Canada Permanent, 5½%	$500.00	
Canada Permanent, 5½%	500.00	
Dominion of Canada, Victory, 5½%	1,000.00	
		$2,000.00

The Society also possesses instruments and lantern slides valued at $1,600, and a library valued at $10,000.

LIBRARIAN'S REPORT

The periodicals received during the year totalled 604. Of these 205 were received from Canada and other parts of the British Empire, 224 from the United States, and 175 from other countries.

The exchange list of the Society numbers 140, the distribution being as follows:— Canada and the Empire, 43; United States, 55; other countries, 42.

Some 37 volumes were bound, and about as many were added by purchase. The library is continually growing in size and value, but the accommodation is far from satisfactory. New quarters are urgently needed.

C. A. CHANT, *Librarian.*

OTTAWA CENTRE

Secretary's Report for 1923

The membership of this centre has increased from 83 to 89. Eleven new members were elected and two resignations were accepted. The deaths of three of our oldest members, two of whom were past-presidents, occurred during the year.

The following lectures, which were well attended, were given before the Society in the Victoria Memorial Museum:—

January 25—"The Einstein Theory and the Australian Eclipse," by Professor C. A. Chant, University of Toronto.

February 13—"Astronomy—A National Necessity," by Dr. R. J. McDiarmid, Dominion Observatory.

February 27—"Prehistoric Life and the Age of the Earth," by Dr. H. M. Ami, Geological Survey of Canada.

March 13—"The Influence of the Sun and Moon on the Ocean," by Dr. W. Bell Dawson, Tidal Surveys.

March 27—"Myths of the Stars," by C. R. Coutlee, C.E., Department of Public Works.

November 13—"The Recording and Study of Earthquakes," by E. A. Hodgson, M.A., Dominion Observatory.

November 20—"The Stars, Electricity and Radiation," by Professor A. S. Eve, McGill University.

The officers for 1924 are as follows:—

President—R. J. McDiarmid, Ph.D.

Vice-President—C. R. Coutlee, C.E.

Secretary—A. H. Miller, M.A.

Treasurer—W. S. McClenahan, B.A.

Council—T. L. Tanton, Ph.D.; E. A. Hodgson, M.A.; Thomas Donoher; and past presidents, R. Meldrum Stewart, M.A.; F. A. McDiarmid, M.A.; J. J. McArthur, D.L.S.; and R. E. DeLury, Ph.D.

A. H. MILLER, *Secretary.*

FINANCIAL STATEMENT, 1923

Receipts

Balance on hand, Jan. 1, 1923	$ 13.67	
Grant from General Treasurer	111.75	
Interest on Bank Account	1.59	
		$127.01

Expenditures

Lectures	$43.10	
Printing	11.76	
Advertising	30.80	
Postage, Exchange, etc.	5.47	
Incidental Expenses, Flowers, etc.	8.55	
Balance on hand	27.33	
		$127.01

Examined and found correct,
D. ROBERTSON, *Auditor.*
Dec. 4, 1923.

Respectfully submitted,
W. S. McCLENAHAN,
Treasurer.

Report from Montreal Centre

The Montreal Centre held its first meeting for this session on December 12, 1923. Owing to certain reasons the officers were unable to arrange for a November meeting.

It was discussed and approved by Committee that a series of elementary lectures be given under the auspices of the Society. The Executive recommended to the members of our centre that a series of lectures on Astronomy be delivered by Professor Gillson under the auspices of the College and that members of the Society be given reduced fees.

The officers for 1924 were elected as follows:—

Hon. President—Mgr. C. P. Choquette, Lic. Scs.

President—Mr. Justice E. E. Howard.

First Vice-President—Prof. A. H. S. Gillson, M.A.

Second Vice-President—H. E. S. Asbury.

Sec.-Treasurer—A. W. Strong.

Recorder—Miss A. V. Douglas.

Corresponding Secretary—Rev. W. T. B. Crombie, M.A., B.D.

Councillors—George Sample; Prof. A. S. Eve, D.Sc., F.R.S.; Julian Smith; Miss M. Ellicot; Mr. Pask.

The Executive asked Messrs. Eve, Gillson and Asbury to arrange for the series of lectures. The lecturer on December 12 was Dr. Howard Barnes, who chose as his subject, "Light and Heat from the Stars". Dr. Barnes gave a masterly presentation of a difficult and technical subject.

Financial Statement for 1923

Receipts

Membership Fees received	$114.00	
Grant from General Society	98.68	
Interest Credits	4.76	
		$217.39
On hand or in Bank, Dec. 7, 1922		76.87
		$294.26

Expenditure

Membership Fees sent to General Treasurer	$110.00	
Expenses of Lecturers	22.50	
Janitor and Lantern Service	14.00	
Printing and Stationery	8.69	
Postage	2.15	
		$157.34
On hand or in Bank, Dec. 12, 1923		136.92
		$294.26

Adopted at the Annual Meeting held Dec. 12, 1923.

Respectfully submitted,

A. W. STRONG,
Secretary-Treasurer.

London Centre

Secretary's Annual Report

The London Centre began the second year in its history with 39 regular members. This was increased during the year 1923 to 46 members in good standing.

During the year eight regular monthly meetings were held. The January meeting was held in the Normal School Auditorium and was open to the public, in order to give all interested an opportunity to hear Dr. Chant's lecture on his trip to Australia. A successful observation meeting was held on the Normal School grounds in May.

The following addresses were given during the year:—

Jan. 12—"An Astronomical Trip to Australia," by Dr. C. A. Chant of the University of Toronto.
Feb. 9—"Winter Stars in Song and Story," by Miss Grace Blackburn.
Mar. 9—"What the Spectroscope Tells us About the Stars," by Prof. W. J. Patterson, M.A.
Apr. 13—"A Popular Presentation of the Einstein Theory of Relativity," by Prof. R. C. Dearle, M.A., Ph.D.
Oct. 12—"Motion in and Beyond Our Solar System," by Prof. H. R. Kingston, M.A., Ph.D.
Nov. 16—"Earthquake and Volcanoes," by Professor J. W. Russell, M.A.

The meetings throughout the year were well attended.

The officers for 1924 are:—

President—H. R. Kingston, M.A., Ph.D.

Vice-President—Miss Grace Blackburn.

Secretary-Treasurer—E. T. White, B.A., D.Paed.

Councillors—Rev. R. J. Bowen, F.R.G.S.; Mrs. S. R. Moore; H. B. Hunter; J. C. Middleton; and W. A. McKenzie.

E. T. WHITE, *Secretary.*

FINANCIAL STATEMENT FOR 1923

Receipts

Balance from 1922 (cash $6.67, Fees in advance $16)....	$22.67	
38 Members' Fees for 1923.....	76.00	
6 Members' Fees for 1924.....	12.00	
Grant from General Treasurer.....	58.50	
Interest on Deposits.....	.86	
		$170.03

Disbursements

Paid Caretaker.....	$ 5.00	
Remitted Fees to General Treasurer.....	92.02	
Printing Notices.....	17.40	
Postage and Stationery.....	1.30	
Dr. Chant's Travelling Expenses.....	7.40	
Transparency Case.....	5.75	
Repairs and Cartage on Telescope.....	7.85	
Balance: Cash $21.31, Fees in Advance $12.00.....	33.31	
		$170.03

Audited and found correct,
(Signed) THOS. COLERIDGE
JNO. C. MIDDLETON } *Auditors.*

E. T. WHITE,
Treasurer.

VICTORIA CENTRE

Secretary's Report

I beg to submit the following report on the activities of the Society for the year ending December 11, 1923.

The following lectures were given:—

Dec. 15, 1922—"An account of the Expedition to observe the total eclipse of sun in Australia," by Dr. R. K. Young.

Jan. 16, 1923—"Meteors and Meteorites," by Mr. J. Duff.

Feb. 5—A joint meeting of the Society and the Vancouver Island Prospectors Association held in the Assembly Hall of the Victoria High School. Dr. Schofield of the U.B.C. on "The Origin of Mountains."

Feb. 27—"X-Rays, their nature and some of their uses," by Dr. L. K. Poyntz.

Mar. 27—Amateurs' Evening. "Light," by Mr. P. W. Maunsell. "The Causes of the Seasons," by F. Moore. "Why a person gains or loses a day when travelling round the Earth," by Mr. P. S. Langton. "Grinding an 8" Refractor," by Mr. J. C. Watters. "Impressions of Mt. Wilson," by Rev. W. Lashley Hall.

May 1—(1) "The Milne Shaw Seismograph," by Mr. F. Napier Denison. (2) "Results of the Australian Expedition," by Dr. R. K. Young. (3) "O-Type Stars," by Dr. J. S. Plaskett.

June 22—Open-air meeting at the Astrophysical Observatory. Unfortunately the weather conditions were very bad, but the Society nevertheless spent a very enjoyable visit.

Oct. 23—"Recent Severe Earthquakes," by Mr. F. Napier Denison.

Nov. 20—"Recent Astronomical Events in California," by Dr. J. S. Plaskett.

Dec. 11—Annual Meeting. "Recent Progress in Astronomy," by Mr. W. E. Harper.

Executive meetings were held on five occasions. The membership was increased from 62 to 66. The President has dwelt on the desirability of the members endeavouring to further increase our numbers. A successful innovation has been the "Question Box", very many interesting questions having been asked and replied to. In view of the above it may be stated that the Society has had an enjoyable and successful year.

The officers for 1924 are:—

Honorary President—Dr. J. S. Plaskett, F.R.S.

President—Mr. J. Duff.

Vice-President—Mr. F. C. Green.

Treasurer—Mr. J. P. Hibben.

Secretary—Mr. F. Moore.

Executive Committee—Messrs. P. H. Elliott, H. Cameron, R. G. Miller, W. H. Christie.

Auditor—Mr. H. H. Plaskett.

F. MOORE, *Secretary.*

TREASURER'S STATEMENT FOR 1923

Receipts

Dec. 31, 1922, Balance on hand	$ 5.31
Feb. 26, 1923, Grant from General Council	91.50
Fees of members: 2 for 1921, 6 for 1922, 24 for 1923, 7 for 1924	78.00
Interest on Bank Account	2.15
	$176.96

Expenditures

Remitted to General Treasurer	$80.00
Stamps and stationery	2.50
Carpentry repairs	9.50
Printing	11.60
Rent	24.50
Balance on hand	48.86
	$176.96

Outstanding accounts: Rent, $10.00; Printing, $9.75.

WINNIPEG CENTRE

The following are the subjects of papers presented at the meetings during the year. The attendance was good and the year's work successful.

Jan. 24—"Early Stages of the Earth's History."—Prof. R. C. Wallace.

Feb. 14—"Einstein Theory of Relativity."—Rev. T. W. Morton, B.Sc.

Mar. 7—"Some Famous Problems in Mathematics."—Dr. N. B. MacLean.

April 11—"Recent Astronomical Discoveries and Photographs." (Illustrated.)—Prof. L. A. H. Warren.

Oct. 24—"The Eclipse of Sept. 10th, 1923." (Illustrated.)—Dr. N. B. MacLean (who assisted at Catalina Island, Cal.).

Nov. 14—"The Atmosphere."—Rev. T. W. Morton, B.Sc.

Nov. 28—"Richard A. Proctor—Astronomer." (Illustrated.)—Mr. D. Richard Proctor Coates (a grandson).

Dec. 12—(Annual Meeting). "Influence of Astronomy on the Growth and Development of Man's Mind and its Value as an Elevating and Intellectual Pursuit."—Mr. H. B. Allan, retiring president.

The officers for 1924 are:—

President—Rev. Father T. W. Morton, B.Sc.

Vice-President—Mrs. E. L. Taylor.

Curator—Dr. L. A. H. Warren.

Secretary-Treasurer—Mr. H. B. Allan (Suite 7, Nassau Apts., Winnipeg).

Councillors—Dr. N. B. MacLean, Mrs. S. C. Norris, Mr. D. P. Morse, C.E., Dr. N. R. Wilson, Mr. J. H. Kolb and Mr. Cecil Roy.

FINANCIAL STATEMENT FOR 1923

Receipts

Balance in Bank, 1922	$115.37
Dues	90.00
Grant from Toronto	70.50
Subscriptions (new telescope)	119.50
Correction	.20
	$395.57

Expenditure

Remitted to Toronto	$ 88.00
Stationery	27.66
Stenographic work (Miss Nash)	23.55
To Mr. H. B. Allan, a/c telescope	100.00
Stamps and Excise	5.61
Expenses re Social	3.18
Caretaker—donation	5.00
Balance in Bank	142.57
	$395.57

(Signed) C. E. BASTIN
A. W. MEGGET } *Auditors.*

THE SPROUL OBSERVATORY EXPEDITION TO OBSERVE THE ECLIPSE OF THE SUN, SEPTEMBER 10, 1923

By JOHN A. MILLER and ROSS W. MARRIOTT

THE Eclipse Expedition from Sproul Observatory of Swarthmore College was located at Yerbanis, a small Mexican village on the National Railway of Mexico about halfway between the cities of Torreon and Durango in the State of Durango, Mexico. There were two chief reasons why this location was chosen, the first being that there were already a great number of very well equipped expeditions situated in Lower California, in Catalina, and in Sonora, over which the western part of the path of totality crossed, so that it seemed unwise to place another expedition in that particular region. Furthermore, we desired to study the motions in the corona during the eclipse by comparing our long-focus photographs with others made at a station, the longitude of which differed from ours as much as possible. Professor W. A. Cogshall of Indiana University mounted a lens of 62½ ft. focus, almost the same as ours, near Ensenada. Before going to the eclipse we had agreed with Professor Cogshall upon a programme in order that plates of the same equivalent exposure might be obtained, so that the comparison of plates might be as conclusive as possible. Professor H. H. Kimball of the U.S. Weather Bureau kindly made a study of records of the Weather Bureau of the Republic of Mexico. From this study, supplemented by data gathered by correspondence, we chose a station as far east as the conditions seemed to warrant. It actually turned out, however, that we might have gone considerably farther east than we did. Yerbanis is almost at the crest of a watershed, has an altitude of 6,250 ft., is in an arid region, and for the past three or four years almost no rain had fallen. This year, however, seemed to be exceptional, and we encountered a good many clouds and considerable rain. The last ten days before the eclipse were cloudy most of the day and practically all of the night, and a good deal of rain fell. The eclipse occurred on Monday, September 10, and on Friday and Saturday

preceding it, it rained all day and all night in deadly earnest. On Sunday the rain ceased and the clouds cleared away long enough to see the sun come down the great tube of the 65 ft. camera at eclipse time. It then clouded over and was cloudy until about noon on Monday. From 9 o'clock a.m. September tenth it rained terrifically for an hour; at 10 o'clock there was a stream of water half an inch deep flowing over every square inch of the camp. The instruments were drenched and so were our spirits, but at noon the clouds broke away, and when the first contact came it was almost clear in the region of the sun. At the beginning of totality there were light clouds floating over the region of the sun, but by the time the eclipse was half over it was practically clear and continued so the remainder of the afternoon. It clouded the night after the eclipse was over and was cloudy until we left there on September 14.

The expedition was financed by the Rubel Foundation and other friends of the College. It was rather generously, though judiciously, supplied with funds, and I embrace this opportunity to express the appreciation of the entire staff to those who made the expedition possible. The personnel of the observing party was: The writer; Director H. D. Curtis of Allegheny Observatory; Professors Marriott and Wright of Swarthmore; Professor Dinsmore Alter of the University of Kansas; Professor Long of Franklin and Marshall College; Adrian C. Rubel and Wilson M. Powell, Jr., of New York, students from Harvard College; Earl L. Williams, George B. Clothier, Bevan Sharples, students from Swarthmore College; and Max B. Miller, Jr., of New York. Mrs. Miller and Mrs. Marriott were two indispensable members of the party, and Alice Elizabeth, the four-year-old daughter of Professor and Mrs. Marriott, was its mascot. Charles Charlton, sent by the Pathe News to make motion pictures of the eclipse and the operations of the observers, was with the party from the beginning.

We set for ourselves the following schedule of observations:

1. Photographs of the corona.
2. Spectrographic observations.
3. Photographs for testing the Einstein Theory.
4. Records of the shadow bands.
5. Motion pictures of the eclipse.

For attacking the first problem we used four cameras, one of 65 ft. focal length, one of 104″, one of 61″ and one of 38″. The lenses for three of these cameras were very generously loaned to the expedition by the Naval Observatory, and the 61″ is the property of the Allegheny Observatory. The 65 ft. lens was mounted so as to photograph the corona directly following in general the way the Lick Observers have mounted their long focus lenses since 1893. The lens was mounted on a tower nearly 50 ft. high. This tower was surrounded by an outer tower which protected the tower carrying the lens from winds and also carried the upper end of the camera tube, the lower end of which terminated in a dark room in which the plates were exposed. The driving clock which controlled the motion of the plate was made by G. W. Klages and Sons of Pittsburgh, and is a most excellent machine. All the other lenses were mounted in tubes fastened to a polar axis. In the focus of the 65 ft. lens we exposed eight plates, the exposures being 5s., 9s., 25s., 55s., 33s., 9s., 5s., 2s. The plates used were the seed No. 30 for the 55s. and 33s. exposures and seed No. 23 for the remainder. This instrument, on the day of the eclipse, was in charge of Professor Marriott and Wilson M. Powell, Jr. In the 104″ and in the 38″ there were exposed seven plates. These were exposed 2s., 4s., 8s., 16s., 32s., 64s., and 2s. In the 61″ four plates were exposed, with times 2s., 21s., 56s. and 64s. The 104″ camera and the 38″ camera were in charge of Mrs. Marriott and Max B. Miller, Jr., respectively, and the 61″ camera was in charge of Bevan Sharples. These photographs have turned out extremely well. They record a very great wealth of fine coronal detail.

The general type of the corona is that of the minimum sun spot period. The 38″ camera recorded two streamers, each of which were 3¼ diameters of the sun from its centre. The 65 ft. camera showed that the corona was a little less complicated than is usual, particularly upon the east side of the sun in which the streamers can be easily traced from the margin of the sun out a distance of ¾ of a diameter. There were three prominences on the eastern edge of the sun which do not seem in any way to have affected the shape of the long streamers. On the southwestern limb of the sun the corona was very much more complex. There is a large eruptive

prominence there and a little to the north of it a series of arches in the corona similar to those of the corona of 1918, but they are less symmetrical and larger. No prominence beneath them is apparent, which probably indicates that they originate behind or in front of the sun instead of at its limb. At a considerable distance above these arches there is an irregularity in the corona that one is inclined to believe is caused by the same thing as that which caused those arches. The polar streamers around both poles are very long, resembling those polar streamers of the usual minimum sun spot corona. There is an additional phenomenon there that I never have seen before. There seems to be at each pole a large sheaf of streamers that probably occur at a comparatively low solar latitude but which are so long that their outer extensions extend beyond the pole. These streamers seem to be sharply curved at their extremity. They are plainly shown on all the photographs of the 65 ft. camera except the very short exposures.

Our spectroscopic programme was somewhat less ambitious. We photographed the "flash" spectrum with two objective gratings. One was a large grating 34″ focal length belonging to Allegheny Observatory, the mounting of which Dr. Curtis designed and built at the Allegheny Observatory. The instrument was in charge of Dr. Curtis. It was mounted on a polar axis and so adjusted that it recorded on stained plates the spectrum well down into the red end. The other grating was a larger one ruled 21,000 lines to the inch, mounted in a similar way, but so adjusted that it recorded the spectrum on the blue side of 5,000. Both these gratings were exposed also on the corona during totality. Professor Wright built an interferometer of the Fabry-Buisson type with which we hoped to detect the motions of the corona. The silvered plates for this instrument were made by the William Gaertner Company of Chicago. The U.S. Bureau of Standards, through its Director, Professor Burgess, prepared and loaned us a set of spare plates which were mounted by Dr. Curtis at the Allegheny Observatory and which we took with us in case of accident.

To search for the Einstein effect we had built by the James B. McDowell Company two quadruplet lenses following the Brashear-Hastings formula. The aperture of these lenses is 6¾″ and their focal length is approximately 15 ft. They are most excellent

lenses. The star images on plates 18″ x 18″ are almost as good at the corners as at the centre. Exposures at Swarthmore and also at Yerbanis showed that on a clear night one could record in 50s. images of stars of 10.4 photographic magnitude. There were 50 stars in the eclipse field as bright or brighter than 9.5 magnitude, and they were fairly symmetrically situated with regard to the sun. These lenses were mounted in a twin tube of structural iron which was carried by a structural iron polar axis. The motion of the corona was controlled by a sector arm. We exposed two plates in each of these cameras. The first one was exposed on the eclipse field for 55s. The telescope then was shifted 10° in declination and a reference field photographed on the same plate. The plates were changed and the reference field photographed on the second plate, the telescope then shifted to the eclipse field and photographed again. The programme differed from that of Campbell's in taking the reference field at the time of and during the eclipse.

After the cameras had been made and the programme worked out, Professor Charles Lane Poor suggested an experiment that would show whether the rays were bent at the sun or some place this side of the sun. He suggested that we make extremely short exposures of the moon on a plate on which a star field had already been impressed. One of his friends and Professor Poor provided a camera and mounting the exact duplicate of the ones just described. With this camera we made three plates on each of two of which we photographed a reference field the night before the eclipse, on the day of the eclipse the eclipse field, and two very short exposures of the moon; on the other the reference field and two short exposures of the moon. These plates have not yet been examined closely enough to speak of their excellence or lack of excellence. The plates used in these cameras were plate glass coated with seed No. 30 emulsion.

We desired, if possible, to get some definite information regarding the shadow bands. It also seemed desirable to have a motion picture made of the eclipse from the time of first contact to the last, as well as some of the operations at the instruments during the time of the eclipse. We presented this matter to the Pathe News who, in a way characteristic of the enterprise of this organization,

undertook the work. They secured the fastest motion picture lens made for photographing the shadow bands. We spread a white sheet upon the ground on which was marked a scale in feet and a north and south line. The face of a watch was so focused by a lens that in one corner of the photograph was recorded the time of exposure and on the remainder of the film was recorded the scale, the north and south line, and we hoped, the shadow bands. In this way we hoped to get the distance between two shadow bands, the direction and the velocity with which they moved. A good many feet of film were exposed, but the shadow bands at this eclipse were extremely faint, perhaps due to the clouds. I have not yet seen this film though we are not hopeful that we secured the shadow bands at all. The moving picture of the eclipse became the property of the Pathe News, but they furnished us copies of the entire film made there and we are at liberty to permit its use for other than commercial purposes. The Observatory, therefore, is willing to send this film on request to such as are interested in it at a nominal expense, which covers the insurance and the cost of transportation.

We desire to acknowledge our deep obligations to the United States Naval Observatory, who loaned us three lenses and a driving clock, and to the Allegheny Observatory for the loan of various instruments mentioned in the body of this article; to the Rubel Foundation who made the expedition possible; and to every member of our staff, for without their skill, enthusiasm, and unselfish interest in the prosecution of the programme, it would have been far less successful. It is a pleasure to acknowledge our very deep obligations to the Government of the Republic of Mexico, which did everything in its power to facilitate the work of the expedition. Our instruments were permitted to enter Mexico without expense and their railroads transported them carefully and promptly. Perhaps more than to any other single person we are indebted to Director Joaquin Gallo of the National Observatory of Mexico because of his uniform courtesy. He put at our disposal not only his personal services in many instances but loaned us at various times small instruments and books. The Governor of Durango sent an emissary to our camp practically every day after its instalment to inquire if they might in any way do things they had left

undone. Our camp was located on the Catalina Hacienda just outside of Yerbanis. The owners of Catalina Hacienda very generously put at our disposal this land. They extended to us every courtesy in their power and it is a pleasure to acknowledge these very great favours. Our entire stay in Mexico will be remembered with the greatest of pleasure.

THE WINTER SKY

By A. Vibert Douglas

THE long winter evenings which follow the early sunset give the star-lover a good opportunity of becoming familiar with the chief glories of the winter sky—those brilliant stars which continually arrest the eye, and those great constellations which climb the eastern sky, bestride the heavens or sink towards the western horizon.

The Pole Star is our starting-point and is of interest apart from the fact that its position in the sky gives approximately the direction of the earth's geographic axis. Polaris is a great multiple star as has been revealed by spectral photographs. The relative positions of the lines in successive spectral photographs are interpreted according to the principle discovered by the great Austrian physicist, Doppler, to mean that in reality there are four stars whose periods of revolution about one another are respectively four hours, twelve years, and twenty thousand years. So great is the distance of this group of stars that even though viewed through the most powerful telescope they appear as but one star of apparent magnitude 2.1. The calculated absolute luminosity is -3.0, that is to say, if Polaris were brought nearer to the Solar System and placed at the standard distance relative to which it is customary to calculate absolute magnitude or luminosity, then it would appear five magnitudes brighter than it does now, which would signify that the light it would then radiate to the earth would be one hundred times more intense. Thus this pivotal star of the heavens, as it seems to us, when, due solely to our own terrestrial rotation, all the other stars appear to revolve about it every twenty-four hours, is indeed a giant of the sky worthy to be the guiding star of the mariner or of the desert caravaner.

Low in the northeast early in the evenings of mid-winter hangs the Great Bear, known also as the Plough or the Dipper, its two "pointers" directed upwards to the pole, its handle curving towards Arcturus, which has dropped below the horizon while yet it was day.

Above Polaris just west of the zenith is Cassiopeia whose outline as a large letter W makes her easily recognizable, together with her so-called "guards", a series of large equi-spaced stars which in reality belong to the constellations of Perseus, just at the zenith, Andromeda further west, and then the great square of Pegasus. Many are the tales of mythology which cluster around these constellations—tales of Cepheus King of Ethiopia and of his wife Cassiopeia; of their daughter Andromeda who was rescued from hideous death by the fearless Perseus; of the flying horse, Pegasus, and of the Great and Little Bears; and of Cygnus the Swan whose brightest star, Deneb, is the head of a cross pointing towards Cassiopeia from the northwest.

Just east of Perseus and outshining all the stars near the zenith is beautiful Capella. Of the constellation of Auriga the Charioteer, Capella stands highest of that wonderful array of bright stars which make the southern part of the winter sky so marvellous a sight.

Orion climbs the celestial equator, a figure full of action, of determination, purpose, *joie de vivre*—the hunter chasing his quarry. This constellation has kindled the admiration and wonder of mankind far back in the early history of modern times—the inspired writers of Job and the Iliad refer to it; and in this sense it stands proclaiming the changelessness of the stellar universe relative to the transitoriness of human life. But it is interesting to consider Orion in the light of modern research as illustrating within itself the great conception of stellar evolution. The word *changeless* is applicable only in poetic fancy. It has no place in the stellar universe, for every star is living its evolutionary life-history. There is Betelgeuse, the large reddish star in the shoulder of Orion; and lower down, below the three-starred belt and the great nebula, there shines that pure blue-white star, Rigel. Both are giant stars, that is, they possess high luminosity due to very low density (much lower than that of air) and large surface area. But whereas the former is a very young giant, the latter has reached what is the last but most glorious stage of its giant life and will as time goes on begin to cool as it contracts and becomes less luminous, passing gradually from giant stage to dwarf stage, and so cooling and shrinking more and more until it arrives at the

RECENT PROGRESS IN OUR KNOWLEDGE OF THE UNIVERSE[1]

By Robert G. Aitken

In his address at the dedication of the Yerkes Observatory in 1897, Simon Newcomb said, "If it be true that in nature nothing is great but man, in man nothing is great but mind, then may knowledge of the universe be regarded as the true measure of progress." Without discussing the validity of the premises which Newcomb himself casts in the conditional mood, let us boldly accept his conclusion and take time this evening to consider the progress we have made in the last thirty-five years by reviewing the increase of knowledge of the universe within that period. The time and the occasion are propitious for such an inquiry, for we are assembled to dedicate another great observatory; and this year, 1923, marks the 450th anniversary of the birth of Copernicus, whose book, "De Revolutionibus Orbium Coelestium," set the feet of men for the first time firmly on the road leading to knowledge of the universe and opened a new epoch in the development of the human mind.

The doctrine of Copernicus was more than epoch-making; it was revolutionary. The earth had been to men, in substance, the entire universe; the heavens a canopy drawn close about the earth; the sun, the moon, the planets and the stars merely greater or lesser lights set in that canopy for the comfort and delight of the dwellers upon the earth. Now they were asked to regard that earth as but a little planet, one of several revolving about a distant sun, and the stars, by implication, as vastly distant bodies that might rival with the sun in actual brilliance. No wonder that such heresy met with the most strenuous opposition; no wonder that only the boldest intellects became converts to it before Galileo, in 1609, turned the first small telescope upon the splendours of the sky and saw in the moons revolving about

[1]Address at the dedication of the Steward Observatory of the University of Arizona, April 16, 1923. Printed in *Science* for November 16, 1923.

Jupiter a system, in miniature, resembling the one Copernicus had described.

I must resist the strong temptation to trace in detail the progress of astronomy through the centuries that followed. It is a brilliant story and one that has been told many times in prose and in verse. No one who has read it can have failed to note that advance in civilization closely paralleled the growth of man's knowledge of the universe, or to realize that this growing knowledge, by bringing man an ever-widening horizon, and ever greater freedom of thought, was a most potent factor in that advance.

Among the many conclusions that may be drawn from a thoughtful reading of this history, two are especially encouraging: First, that progress in astronomy has been continuous. From the days of Copernicus and Galileo the observations and generalizations made by any generation of astronomers have afforded the foundation upon which their successors could securely build. We have never had to go back and begin entirely anew, and even in our own times, observations of comets, of eclipses and of other objects and phenomena, made at dates preceding the invention of the telescope by many centuries, have been utilized to advance our knowledge. Secondly, that progress has been made at an ever accelerating velocity. At no period in history has the advance been so great as within the last few decades; and at no time has the promise for an increase of knowledge of the universe been as bright as it is to-day.

It was on June 1, 1888, almost precisely thirty-five years ago, that the newly completed Lick Observatory passed formally into the possession of the University of California and began its active work. Contrast the position of the astronomer at that date with his position to-day. The era of great telescopes was just opening; astronomical spectroscopy and photography were in their infancy; engineers were just beginning to develop practical methods of utilizing electricity as a motive power.

Since then four great observatories, besides the one at which we are gathered to-day, have been built on our own continent and several older ones have been rebuilt. If the advance in this respect has not been quite so great on other continents, still it has been remarkable everywhere and, in all, fully a score of powerful

telescopes have been added to our equipment for exploring the universe. Particularly notable has been the development of the reflecting telescope since Keeler's work with the Crossley Reflector in 1898-1900 demonstrated the great efficiency of this type of instrument in many kinds of astronomical photography.

Coincident with the growth in the size and number of our telescopes has been the invention and improvement of auxiliary apparatus to utilize their great light-gathering powers in new ways and to increase the accuracy of our observations. The modern spectrograph, the spectro-heliograph, the precision photometers of various types, the bolometer, the pyrheliometer, the interferometer, the periodograph, have all come into use within the period I have named. Electric power and light are to-day as indispensable in our domes as in our most progressive industrial plants, and photographic observations have virtually displaced visual observations in all but a few lines of astronomical research.

Such greatly increased facilities, together with the remarkable progress in physics, in chemistry and in the methods of mathematical analysis, have put it within the power of astronomers to enter upon the study of a whole series of questions relating to the stars as organisms which earlier investigators had left practically untouched; not because they took no interest in them or failed to appreciate their importance, but simply because to them it seemed hopelessly beyond the power of the human mind to devise means of securing the data needed for their solution. It is in investigations along these lines that some of the most striking advances have recently been made, but the increase in our knowledge of stellar motions and of stellar distances is fully as great and as important.

The analysis of stellar radiations with the aid of our powerful spectrographs has enabled us not only to classify the stars according to the quality of their light but also to measure with high precision the velocities of the stars in the line of sight, and to discover, and even to compute the orbits of binary star systems that must forever remain invisible[2] to us, no matter how greatly our telescopes

[2]That is, no telescope can show both components of the closer spectroscopic binary stars, especially if they are unequal in their brightness. One component, or the unresolved image of the pair, must, of course, be visible.

may be increased in size. We have made at least a beginning in the measurement of the temperatures, the masses, the densities, the angular and linear dimensions of the stars. We recognize "giant stars" and "dwarf stars"; stars intensely hot as compared with our sun and stars that are relatively cool; "young stars" just emerging, it may be, from an antecedent nebular stage, and "old stars", nearing the end of their history as luminous bodies. It would be easy to continue this catalogue until it filled many pages and to draw up one equally long of the achievements in researches relating to the structure of the stellar system. But it will be of greater interest, I think, to select one of them for more detailed presentation to illustrate modern methods and results.

Let us then consider a problem that has a history dating back to the days of Copernicus, the problem of determining the distances of the stars. The fact that the stars did not change their apparent position or direction from the earth in different seasons of the year, as they should do because of the earth's revolution about the sun, was regarded by the opponents of the Copernican doctrine as one of their strongest arguments against it and was the chief reason why so great an astronomer as Tycho Brahe rejected the doctrine. The proponents of the theory could only reply that the stars must be very far away, but all their efforts to find out how far did not yield a single stellar distance until nearly 300 years had elapsed. Their work was by no means all in vain, for though it did not achieve the end for which it was undertaken it did lead to the discovery, by Bradley, of the phenomena of aberration and nutation and to the discovery, by Herschel, of the existence of the binary star systems. Moreover, it served to set a minimum limit to stellar distances, a limit that receded ever farther as instruments and observing methods improved. Even before the telescope was invented it was clear that the limit must be about 200 times the distance from the earth to the sun, for a lesser distance would cause displacements that could be detected by the unaided eye; by the middle of the 17th century it grew to 4,000, early in the 18th century, to 20,000 or 30,000 times that distance. By the 19th century astronomers had become convinced that the nearest stars must be at least 200,000 times as far away as the sun, or, in technical terms, that the largest stellar

parallax could not much exceed a second of arc. This term, parallax, is a convenient one and I shall use it in what follows. It signifies the angle at the star between lines drawn from the star to the sun and to the earth, respectively; the farther away the star, the smaller the angle. Having this angle, we readily determine the distance, for in the triangle, earth, sun, star, we know one side, namely, the distance from the earth to the sun, and all the angles.

Finally, in the years 1838-39, three astronomers, working in different places, with instruments of different types, announced almost simultaneously the parallaxes of three different stars; Bessel, the parallax of 61 *Cygni*, measured with the heliometer, Henderson, the parallax of Alpha *Centauri* determined from meridian circle observations, Struve, the parallax of Alpha *Lyrae*, from micrometer measures with his equatorial telescope. Success being thus achieved, after nearly three centuries of unavailing endeavour, it might have been anticipated that knowledge of stellar distances would grow rapidly, particularly in view of the constant improvement in instruments and the ever better understanding of the requirements of the problem. Actually, however, progress was slow. By 1880, it is fair to say, we had approximate values of the distance of but a score of stars; by 1900, of some three-score, only, and the prospects for rapid or great increase in number by visual observations were by no means encouraging.

But by this time methods of photographing the stars and of measuring their positions on the resulting plates had been developed to such a degree that it seemed feasible to attack the extremely difficult problem by the photographic method. Pritchard, at Oxford, indeed, had taken a large number of photographs for this purpose as early as the years 1887-1889, and these had led to the parallaxes of 28 stars. His work deserves high praise, even though it has since been found that his results are affected by systematic errors of considerable size. Early in the present century, however, when Kapteyn had definitely enunciated the "reasonable precautions" that must be taken by the observer, first at the telescope and then at the measuring microscope; when Turner and others had developed the exceedingly accurate modern methods of plate measurements; when Schlesinger had shown how to eliminate in large degree the very troublesome "guiding error"; then it became

possible to enter hopefully upon a greatly extended programme of parallax work.

In the meantime astronomers had been learning the lesson so thoroughly drilled into the heads of baseball and football men by their coaches—that good teamwork is fully as essential to the winning of games as brilliant individual play. Co-operation in astronomical research was by no means a novelty in the latter half of the 19th century, but in the 20th century it has become one of the distinctive features of our work. The photographic determination of parallaxes affords an excellent illustration. While each individual guards and preserves his right of initiative, astronomers at seven observatories, six in America and one in England, have formulated a co-operative programme that ensures the elimination of useless duplication of labour and as great a degree of homogeneity in the results as differences in instrumental equipment and observing conditions will permit. Now they are engaged in that most generous form of rivalry in which each one gives all the others the benefit of any improvement in methods of manipulation or of computation he has devised, applauds every success the others achieve, and strives for even greater success himself. It is, therefore, not surprising, though extremely gratifying, that by 1915 we had the parallaxes of at least 200 stars and that now the number is well past the thousand mark and is growing at the rate of perhaps 150 to 200 a year.

At the same time we must face the fact that the number of stars whose parallax can be measured directly with the best of modern telescopes and with the most scrupulous attention to every detail of observation and measurement is strictly limited and pitiably small in comparison with the total number even of the brighter telescopic stars. In 1915, Sir Frank Dyson considered $0''.02$ the smallest parallax that could be measured with any reasonable degree of accuracy. Translated into other terms, this means that if a star is more than ten million times as far away from us as the sun is, we can hardly hope to measure its distance. To-day, eight years later, this may perhaps be regarded as a rather conservative statement, but even to-day no responsible astronomer would care to set a limit very much greater. It is true that by any terrestrial standard of distance 10 million times that to the

sun is enormous, and that no human intelligence can comprehend it. Yet we have every reason to believe that the stars within a sphere of space of this radius do not number more than 20,000 to 25,000 (half of them probably too faint for photographic parallax measurements), whereas the number in our stellar universe is of the order of 1,000 million.

We now open a new chapter of our story. There is an obvious relation between the apparent brightness of a luminous object, its intrinsic or true brightness and its distance from the observer. Two lights may appear to be of equal brightness, because they really are equally bright and are at the same distance from us, or because the one of greater intrinsic brightness is farther away, the law of variation of brightness with changing distance being the well-known law of the inverse square; double the distance and the light is diminished to one fourth its former brightness; halve it and the light is increased fourfold.

Thanks to the efficiency of modern photometers and to the extensive and skilfully executed researches which have led to an accurate scale of visual and of photographic magnitudes, we can now determine with all desired accuracy the apparent brightness or magnitude of any star down to the faintest ones revealed by our telescopes. If then, by some means, we can also determine its *intrinsic* brightness or its "absolute magnitude" (the magnitude it would have at a definite distance from us) it is clear that its distance becomes known. But how is it possible to know anything about the actual luminosity of a star until we know how far away it is? As recently as the opening year of the present century the problem might well have been declared insoluble. Fifteen years later the answer was found in the correlation between the relative intensities of certain spectral lines and the intrinsic brightness of stars of the same spectral class.

This is not the place for a detailed explanation. It must suffice to say that we have ascertained from laboratory experiments and from solar observations that the character and intensity of certain spectral lines are strongly affected by changes in the physical conditions in the light source. Now, "if two stars which have closely the same type of spectrum differ greatly in luminosity it is probable that they also differ greatly in size, mass and in

the depth of the atmospheres surrounding them. Accordingly, we might hope to find in these stars certain variations in the intensity and character of such spectrum lines as are peculiarly sensitive to the physical conditions of the gases in which they find their origin, in spite of the close correspondence of the two spectra in general." Adams, whom I have been quoting, was not the first to search for such lines, but it was he who first succeeded in using them to determine stellar parallax. His paper describing the method was published in 1916; five years later he and his collaborators were able to publish a list of the parallaxes of 1646 stars; and these values are of the same order of accuracy as the best photographic ones.

The method has not as yet been successfully applied to stars of all spectral classes, but we may look forward with confidence to its further extension. Thousands of stellar spectrograms, taken for other purposes, are also available at several of our great observatories, and it is certain that many of these will be utilized for parallax determinations by this new method. Great, therefore, as has been the recent advance in knowledge of the distances of individual stars, the prospects are bright for still more rapid progress in the coming years. For there is, practically, almost no limit to the number of the stars whose distances can be measured by the spectroscopic method. To determine uniquely the absolute magnitude of a star we need only spectrograms on a scale sufficiently large to record accurately the relative intensities of the spectrum lines, and as our instrumental equipment grows more powerful we may hope to get such spectrograms of ever fainter stars.

I have treated this problem of the determination of stellar distances at considerable length not only because of its intrinsic importance in our studies of the structure of the universe, but because it illustrates admirably many of the characteristics of modern astronomical research, and, in particular, the fact that advance in any one line is so closely correlated with and dependent upon advance in others which are seemingly entirely unrelated to it. Nothing, for example, could have been farther from the thoughts of those who were investigating the behaviour of the spectra of gases under different physical conditions than that their results would be applied to the determination of the distances of the stars.

Let me now continue my story by reviewing more rapidly some of its other developments. The determination of the position of stars upon the surface of the celestial sphere is one of the oldest forms of astronomical observation, dating back to the days of Hipparchus. The first catalogue giving star places of sufficient accuracy for comparing with modern meridian observations is Bradley's, about the middle of the 18th century. Since then, by the patient, skilful labour of scores of able astronomers an enormous mass of data has been accumulated and made available for analysis by statistical methods. Comparison of the positions of stars observed at different dates shows that these are changing; slowly, indeed, but in many instances rapidly enough to make the change measurably great within a few years or decades or a century or two. Herschel utilized the scanty knowledge of such motions—proper motions, we call them—available in his day to prove that they were due in part to the actual motion through space of the solar system itself; and with the insight, and, may I add, the good fortune of genius, he was able to estimate the direction of this motion with amazing accuracy.

It is obvious that the motion of the sun through space provides the astronomer with an ever-lengthening base line from the extremities of which he can observe the positions of the stars and hence their "parallactic" displacement. These observations do not lead to the distance of any particular star, because the star's own motion is a factor in its displacement; but, assuming as a first approximation that the stars are moving quite at random; that, in the average, in any given area of the sky as many stars are moving north as south, east as west, towards us as away from us, they do lead to a knowledge of the *average* parallactic displacement of the entire group and hence to the *average* distance of the stars in it. Within the past twenty-five years men like Kapteyn, Campbell, Boss, Dyson, Charlier, to name but five of an illustrious company, have been engaged in a series of brilliant researches on the motions of the stars. Campbell, it is true, has been concerned entirely with the motions of the stars in the line of sight, as determined with the spectrograph, but it will appear immediately that his measures have the greatest significance in the questions I am discussing. Remarkable, indeed, are some of the results

obtained. Thus Boss demonstrated that a number of stars apparently unrelated and widely scattered in the region of the constellation *Taurus* are really moving together through space along practically parallel lines. The spectrograph supplied the radial velocities of a few of the brighter members of the group, and the combination of the data on simple geometrical principles led directly to an accurate knowledge of the distances of every star in the group. Several such "moving clusters" are now recognized and are the subjects of fruitful study.

Still more striking was the announcement by Kapteyn, in 1904, that the stars as a whole are divided into two great streams moving towards vertices at two diametrically opposite points in the plane of the Milky Way. The stars of the two streams are thoroughly intermingled and members of either stream are to be found in every part of the sky, being distinguishable only by their motions. This conclusion has been abundantly verified by later investigations and stands as one of the most important contributions yet made to our knowledge of the stellar system.

Again, Campbell and Boss, quite independently and almost simultaneously, announced that the stars of different spectral classes are moving through space with different velocities.[3] The stars of Class B, the blue white stars, at one end of the series of spectral classes, have the smallest average velocity; and the velocity increases, class by class, as we pass from the white stars through the yellow stars on to the red stars of Class M at the other end of the series. Each investigator gave values for the average velocity, and also for the average parallax of the stars in each group; Campbell from an analysis of the radial velocities of the stars after making correction for the sun's motion through space, the velocity of which his researches measured for the first time, Boss from a similar analysis of the proper motions; and the two sets of figures were in excellent accord.

---

[3]Kapteyn's independent investigations led him almost simultaneously to the same general conclusions. More recent investigations indicate that this apparent correlation between velocity and spectral class may prove to be, physically, a correlation between velocity and mass, the less massive stars having the greater space velocity.

Carrying his work still farther, Kapteyn was able to calculate the approximate *average parallax* or distance of stars of every order of magnitude and of every spectral class. Thus, these diverse researches on the distances of individual stars, on star positions and proper motions, on radial velocities, and on the quality of lines in stellar spectra are all made to focus upon the great fundamental problem of the form and structure of the stellar universe.

I have by no means enumerated all the investigations which bear upon this great problem. I have said nothing, for example, of the binary stars. I might show how they lead us to a knowledge of stellar masses and densities; and, conversely, since we find the range in mass to be relatively small, how we can compute the "hypothetical parallaxes" of the visual binaries (as Jackson and Furner have recently done for more than 550 pairs) by assuming an average value for the mass. Or I might ask you to consider the variable stars, and especially the Cepheid variables, and show how Miss Leavitt's discovery that in the Cepheids in the Smaller Magellanic Cloud a definite numerical relation exists between the magnitude of the star and its period, that is, the length of one complete cycle of light variation, enabled Hertzsprung to estimate the distance of the Cloud itself and put into the hands of Shapley a new gigantic "yard-stick" with which he has measured the distances of the globular star clusters and the dimensions of the stellar system.

The precise length of this yard-stick depends upon the absolute magnitude of the nearer Cepheid variables, and it may well be that further observations will modify to some degree the value adopted by Shapley; the *validity of its use* rests upon the assumption that the relation between magnitude and period which holds for the Cepheids in the Magellanic Cloud is independent of the star's environment and characterizes these variables wherever they appear, whether in space comparatively near us or in the most distant star cluster. The assumption has been challenged and it is not impossible that it may prove to be invalid; but it is supported by so much corroborative evidence that it commands ever more respect and credence.

A similar remark applies to many other generalizations as to the structure and dimensions of the universe. *Quantitatively*, they

are admittedly approximations which are to be corrected and improved as additional data of observation are accumulated. They also involve *assumptions,* some of which can not be submitted to direct tests, but which are adjudged valid because they seem to be in harmony with accepted physical laws and give results which agree with observation. Some of them, no doubt, will have to be modified; some may have to be abandoned entirely. But it is certainly an inspiring fact that, imperfect and limited as our knowledge is, it is yet sufficient to have enabled Kapteyn, in the last paper published before his death last year, to formulate—with hesitation and some misgivings, it is true, but yet with confidence in the principles involved—"a tentative theory of the dynamical organization of the stellar universe."

The researches which I have been reviewing relate chiefly to one of the two fundamental problems of astronomy; the other is that of stellar evolution. This is distinctly a problem of our own times, one that could not be attacked until spectroscopy and photography had been successfully applied in stellar observations, until modern methods of solar research had been developed, and physicists and chemists had given us a better insight into the properties of matter and especially of matter in the gaseous state.

Observationally, stellar spectra provide the first and by far the most important data for the study of stellar evolution, and for the vast accumulation of such data now available astronomers gratefully acknowledge that they are indebted most of all to the late Professor Pickering and his colleagues at the Harvard College Observatory. The monumental "Henry Draper Catalogue of Stellar Spectra," of which seven volumes have already been distributed, contains the classified spectra of more than 200,000 stars. The first remarkable fact to be noticed is that fully 99 per cent. of all the stars whose spectra have been examined fall into one or the other of only six great groups, designated by the arbitrary letters B, A, F, G, K and M. The next is that these groups grade into each other in such a way as to form a continuous linear series, the colour deepening from white through yellow and orange to red as we pass from B to M. The classification is on an empirical basis depending simply upon the characteristics of the spectral lines; but the continuity and particularly the linearity of the series

is strong evidence, in Russell's words, "that the principal differences in stellar spectra, however they may originate, arise in the main from the variations in a single physical condition in the stellar atmosphere." All astronomers now agree that this dominant physical condition is temperature, a conclusion that has been abundantly confirmed. We have even been able to measure stellar temperatures directly by the use of extremely sensitive thermocouples in conjunction with some of our great reflecting telescopes, and thus have definite knowledge that the intensely white Class B stars are the hottest, the red Class M stars the coolest in our series. These facts point to a genetic or evolutionary relationship between the stars of successive spectral classes; the question is as to the direction in which the evolution proceeds.

Within the past decade data for the discussion of this question and the related question of the status of matter antecedent to the stellar stage have been offered in such abundance, in such variety and in such rapid succession as fairly to bewilder the conservative mind. The astronomer has been applying his telescope to the measurement of the radial velocities of the nebulae and has found not only that the planetary nebulae are moving at speeds greater than those of the most rapidly moving stars (on the average), but that the velocities of the spirals are so much greater still as to be of an entirely different order. He has found that the planetaries, with but few apparent exceptions, are rotating on their axes; he is adducing ever stronger evidence that the matter in the arms of spiral nebulae is moving outward along the curves of the arms. He has shown that the great diffuse gaseous nebulae have such low velocities as to be practically at rest with respect to the stellar system; and, further, that diffuse nebulous matter capable of obstructing rather than of radiating light is extraordinarily abundant. He has studied the distribution in the sky and especially with reference to the galactic plane, of stars of different spectral characteristics, of binary stars, of variable stars, of nebulae of the different types, and has found, for example, that the red stars of Class M, whether bright or faint, are distributed over the sky almost at random and that they exhibit no relationship of position to the diffuse nebulae, whereas the stars of Class B, among others, are strongly concentrated towards the plane of

the Milky Way and show a marked apparent affinity for the diffuse nebulae.

While observatories and astronomers in all parts of the world have been making effective and valuable contributions in such researches, it is a matter of legitimate pride that the astronomers in our own country, using our great modern telescopes, and particularly those in our Pacific area, have been among the leaders in nearly all of them.

All this material and far more, including the ever-growing volume of data on the visual and spectroscopic binary stars, on variable stars and on solar phenomena, the astronomer is placing at the disposal of the student of stellar evolution; and it is only fair to say that the latter is availing himself of it all and of all the progress made by physicists and chemists in their researches on the properties of matter, eagerly and effectively. It would be interesting, did time permit, to follow in detail the development of evolutionary theory during the past thirty-five years, but, passing scores of valuable contributions by Schwarzschild, Eddington, Jeans and many others without a reference, I can only take time to present most summarily and imperfectly the theory which now, in its general features, commends itself strongly to the majority of astronomers. It was first proposed by Lockyer, so far as its fundamental principle goes, but it has been so expanded and enriched and in many features so radically modified by Russell and so brilliantly presented and defended by him that we commonly refer to it as Russell's theory.

Briefly, the theory assumes that in the beginning of their stellar stage all stars are of Class M. They are then bodies of gas of extraordinarily low density and of low temperature and surface brightness. As they contract they grow ever hotter and pass through the successive spectral classes towards B, but only the more massive stars can generate heat enough to reach the white-hot state required to produce spectra of Class B; the others reach their critical density at spectral Class A, F, G or even K. After this critical point in their contraction is reached the stars begin to fall off in temperature and in luminosity and gradually pass through the spectral classes in the reverse order until they again become red stars of Class M before they finally sink to invisibility.

The stars on the ascending branch are, in the terminology introduced by Hertzsprung, chiefly "giants," those on the descending branch chiefly "dwarfs," the terms "giant" and "dwarf" referring to luminosity rather than to mass.

On this theory the very bright red stars of Class M must be giants of enormous volume to compensate for their low surface brightness. On the basis of observational and theoretical data Russell and Eddington, independently, calculated the "hypothetical" diameters of some of these stars, and it is one of the most cogent arguments in favour of the theory that the recent interferometer measures of Betelgeuse and of Antares at the Mount Wilson Observatory, which constitute one of the most brilliant achievements of modern observational astronomy, are in excellent agreement with these predicted values.

Innumerable difficulties remain to be overcome, innumerable questions to be answered; but in the investigation of stellar evolution as in the investigation of the form and dimensions of the stellar universe, we may at least feel that our feet are set firmly on the road to fuller knowledge.

What of the future? Prediction would be worse than vain. Who, thirty-five years ago, could foresee the discovery of star-streaming, of the correlation of stellar velocity with spectral class, of the applicability of stellar spectra to the measurement of stellar distances? One thing, and only one is certain. Never have the opportunity and the need for good work, well-planned, skilfully executed work, in observational astronomy been as great as they are to-day. In his able address to the American Astronomical Society, Schlesinger recently presented the urgent need of extensive observations of star positions to provide further data on proper motions. It would not be at all difficult to show at least equal need for measures of the radial velocities of stars and nebulae; for measures of stellar distances; for photographic investigations of nebulae and of star-clusters; for qualitative studies of stellar and nebular spectra; in brief, for extensive additions to every form of observational data on the motions and radiations of the nebulae and of the stars.

To secure these additions to our knowledge we must have observatories equipped with powerful modern telescopes and their

accessory instruments, and we must have more trained observers. For material equipment and support we must look to a generous public and we shall not look in vain if we, who are learning a little about this great universe of ours, tell what we learn and make it part of the common knowledge of our time. For trained observers we must turn, first of all, to the students of our universities. I count it, therefore, a matter for special congratulation that this new observatory, the gift of a private citizen, a public spirited woman, equipped with the first powerful telescope whose *optical* as well as mechanical parts were all made in our own country, located in a most favourable climate, and directed by an able astronomer of wide experience, is so closely associated with a vigorous and rapidly developing university. It will be its high privilege not only to make significant contributions to our knowledge of the universe—knowledge that promotes the progress of which it is itself the true measure—but to inspire eager youth who, when we of the older generation one by one lay down the torch, will

> Take . . . . the splendour, carry it out of sight
> Into the great new age (we) must not know
> Into the great new realm (we) must not tread.

REVIEW OF PUBLICATIONS

The Astrophysical Journal: A General Index to volumes 26 to 50. University of Chicago Press, 112 pages 7 x 9½ inches, price $2.50 (paper).

This *General Index* is of the same size and style as the *Astrophysical Journal* itself and is uniform with the previously published index to volumes 1 to 25. It has been compiled by Prof. Storrs B. Barrett of the Yerkes Observatory and is indexed by author and by subject.

It is hardly necessary to speak of the great value of such a book to any library or person who possesses a set of this well-known authority on astrophysics, and indeed it would be useful to anyone in search of information on this subject.

C. A. C.

Annuaire pour l'An 1924 publié par le Bureau des Longitudes. Paris, Gauthier-Villars, 828 pages, 3¾ x 5½ in., price 6 francs.

This well-known publication is now 128 years old. It is divided into five principal parts, which give much information regarding the calendar, the earth, astronomy, weights and measures, physical and chemical constants. There are also biographical sketches of Abraham Breguet by Picard and of Louis Favé by E. Fichot; and scientific papers on "The problem of the Time" by G. Bigourdan, "The Distances of the Stars" by M. Hamy, and "The Scientific Work of Copernicus" by the same writer.

There is no annual printed in English which can compare with this little encyclopedia, either in the richness of its contents or the smallness of its cost. C. A. C.

A Universal Sundial: Description of an instrument which can be set up by anyone so as to give correct time in all countries, by J. K. E. Halm, Ph.D. Published by the Astronomical Society of South Africa, P.O. Box 2061, Cape Town; 20 pages with 2 charts and a map of South Africa. Price 2 shillings.

The sundial described in this paper is a simple instrument designed chiefly for use in places beyond ordinary telegraphic connection. It is constructed on strictly scientific principles, can be made and used by any person without a knowledge of astronomy, and will show the time with an error not exceeding one minute.

The two charts in the publication are to be pasted on two wooden blocks 6 inches square joined at one edge and making a right angle with each other. A supporting leg allows the dial to be adjusted for latitude and the shadow is cast by a silk thread.

Full details regarding construction, adjustment, theory and use are given in the publication. C. A. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

LISTEN

A seat on the Cassiopeian stars,
  A quill from the Eagle's wing,
Papyrus gleaned from the fens of Mars,
  With ink of darkness and leave to sing:

I would set my song to a larger theme
  Than shepherds blow from the reeds of Pan;
    I would croon to the beat
    Of the Centaur's feet
  In tracks where the hounds of Boötes ran;

For I should listen across the night,
  And hear the tones of that mightier word
That sings in a far intenser light
  The strains of a deep eternal chord.

—*From "The Poetical Works of Albert Durrant Watson."*

The Riddle of Mars

During the coming summer the planet Mars will be a very prominent feature of the heavens. As shown by the diagram on page 23 of the HANDBOOK, its distance from the earth on April 15 will be 101,441,000 miles, and this will steadily diminish until on August 22 it will be only 34,648,000. This is an exceptionally close approach, and the planet will then have a stellar magnitude of −2.7, or a brightness nearly three times that of Sirius.

Many will peer into the face of the ruddy warrior in the hope of solving the puzzle of his wrinkles, and it is to be hoped that fresh information regarding their significance will be secured. Of late nothing has been heard regarding the proposal to utilize a mine-shaft in South America as a tube of a reflecting telescope in which the mirror will be the surface of rotating mercury. This is a visionary scheme, and if funds are available for scientific investigation it would be much better to spend them upon projects which can be carried out successfully.

In view of the great general interest which will certainly be aroused the *New York Times* in a recent issue devoted almost a page to an article on Mars by Flammarion, the well-known French astronomer and long-time student of the planet. This veteran scientist always writes in a characteristic and picturesque manner and presents his views in an interesting way. He closes his article thus:—

It is evident, however, that this celestial neighbour of ours is by no means in the dead or frozen state of which it has been accused; it is a very much alive world.

And we have not yet mentioned the canals, their enigmatic aspect and their variations—a network whose first interpretation was that it had been constructed by engineers. This mystery, too, is as yet unexplained. Not all eyes see the more narrow canals, and some even go so far as to deny their existence—a singular exaggeration!

My learned friend Lowell (who used to come to Paris every other year, when Mars could not be observed), discussed with me a whole theory of their application to the distribution over Mars of water, which is rare there and essential for agriculture. Even before that, the eminent astronomer Schiaparelli, to whom science owes the discovery of the cometary origin of shooting stars, and who, in 1882, constructed the first really complete map of Mars, had written me in connection with this odd network: "Semel in anno licet insanire" (once a year we may speak out mad fancies).

At that time he presented to me an ingenious and picturesque hypothesis, supported by diagrams, concerning the construction of the canals by Martian agriculturists for the irrigation of the land. I believe, however, that these canals might be primitive geologic formations, say, valleys, that were elaborated by the inhabitants; for the network as we see it to-day seems hardly natural.

The coming Summer may tell us more about Mars than we have ever known. That astronomers, both scientific and popular, are eagerly awaiting the close passing of our celestial neighbour goes without saying.

A Young Moon Misbehaving Again

Stephen Graham in "Tramping with a Poet in the Rockies" reports the following behaviour of a young moon:

The mountains were compact and black and clear, and a dim light behind them glorified each. A young moon arose and poised herself above us, and only slowly and very unobtrusively crept across the sky. (Chapter XVII.)

In a few days, however, the young thing had grown wiser and conducted herself more nearly as one would expect her to:

A half moon rose over us at nightfall and marsh hens sped through the air in volleying groups of ways. (Chapter XXII.)

Professor Russell's Lectures at Toronto

On the invitation of the Board of Governors of the University of Toronto, Professor Henry Norris Russell, director of the Princeton University Observatory, delivered a special course of fourteen lectures, beginning on February 12 and continuing until February 29. The subject was "Applications of Modern Physics to Astronomy," and it was treated according to the following synopsis:—

I. *The extent of the universe*—Distances and motions of the stars; Motion of the sun; Its use for measuring greater distances; The brightness of the stars; Apparent and absolute magnitudes; Star colors and their measurement; Variable stars, and their use in determining great distances; Distances of star clusters and the Milky Way.

II. *The sizes and masses of the stars*—Stellar diameters; Eclipsing variables; Interferometer measures; Stellar masses; Binary stars; Slow-moving pairs; Relation of mass to brightness; Similarity of masses; Dynamical parallaxes; Stellar densities; Giant and dwarf stars.

III. *The analysis of light*—The observation of spectra; The origin of spectra; Modern atomic theory; Excitation and ionization of atoms; The interpretation of complex spectra; Black-body radiation.

IV. *The analysis of stellar atmospheres*—The sequence of stellar spectra—its dependence on temperature; Temperatures found from color-index or heat-index; Stellar diameters; The effects of density; Spectroscopic parallaxes; Saha's theory of ionization; Pressure in stars; Electron haze; Problem of the photosphere.

V. *The constitution and evolution of the stars*—The interior of a star; Radiation pressure; Eddington's theory; What determines stellar masses; Relation between stars and atoms; Stellar evolution; Giant and dwarf stars; Influence of mass; The B-stars; The time scale; Age of the earth and sun; Probable origin of the solar system; Sources of stellar energy; Special problems; Cepheid variables; Long-period variables; Novae.

VI. *The nebulae*—Dark nebulae—their abundance, size and probable nature; Galactic nebulae—gaseous and otherwise; Appearance; Spectra; Relation to stars; Source of luminosity; Probable nature; Non-galactic nebulae—spiral and globular forms; Spectra; Motions; Probable size and distance; Jeans's theory of their nature.

The lectures were usually at 5 p.m. but the first one and those on Thursdays were at 8 p.m. In his presentation of the various topics the lecturer did not hesitate to use mathematics, but the line of reasoning and the results were expressed so clearly that the amateur scientist could appreciate them.

The attendance was excellent. It consisted of members of the faculty of the University, graduate and undergraduate students and interested laymen. Among the visitors from beyond Toronto were Mr. R. Meldrum Stewart, Acting Director of the Dominion Observatory at Ottawa, and Dr. Ludwik Silberstein, Research Physicist of the Eastman Kodak Co., Rochester, N.Y. At the first lecture about 325 were present. The topic was the extent of the universe and it was discussed by the lecturer in an elementary manner. The usual attendance when the course was well in progress was from 50 to 100 and this continued daily, many missing scarcely a lecture, and following the various subjects very closely.

In addition to the above regular course, Professor Russell delivered on February 16 a popular lecture on "The Nebulae, Dark and Bright," to a large meeting of the Royal Canadian Institute. He also conducted two informal conferences on Saturday mornings and addressed members of the faculty and graduate students on the manner of tracking down series in spectra, illustrating the method by means of his own work on the titanium spectrum.

On the evening of the last lecture an informal farewell dinner was tendered to Professor Russell in the Faculty Union in Hart House. Sir Robert Falconer, President of the University, occupied the chair and about 35 of those who had attended the lectures were present. In the course of the proceedings it was strongly urged that the lectures be printed, since they embodied the very latest results in astrophysics, including some of the lecturer's unpublished work. Moreover, it was stated that inquiries regarding the publication of the lectures had been received from various parts of the United States and Canada. With the object of assisting in the publication, an experienced shorthand writer had been engaged to take down the lectures as they were delivered. Owing to the somewhat technical nature of the subject and also the rapidity of the lecturer's delivery (not inappropriately compared by a friend to the velocity of light) the stenographer experienced great difficulties. The report has not yet been completed but the present writer believes it will be well done. Professor Russell expressed his willingness to use the notes when transcribed as a basis for a text for publication. Astronomers and physicists everywhere will hope that the publication will not be delayed long. An outline

of the lectures prepared by Mr. H. F. Balmer will be printed in this JOURNAL, beginning in the next issue.

As the members of the party were separating, Mr. A. F. Miller addressed a few graceful words to Professor Russell, which at my request he put in writing, as follows:—

This evening you spoke with appreciation of the regular attendants at your lectures. As one of these I come forward to wish you good-bye. At the same time, though only a humble amateur worker in astro-physics, I cannot resist expressing my indebtedness for your admirable exposition of the latest results of those profound researches in which you and your confreres are engaged. Your hearers have been enlightened as by a new star; not a *nova* of sudden but transient brilliance, but rather, as though a bright star, previously beyond our range, had become visible by an extension of our horizon. We class you then as one of the Giants—I will say, a "White Giant"; and the new light you gave us has been a continuous spectrum complete throughout its whole extent, but with many bright lines, fixing definitely in our minds new truths springing from recent discoveries. There were dark lines too, sometimes dark bands, inseparable from the radiations of great stars, but if these *seemed* dark and difficult to understand, I fully realize (speaking for myself) the cause lay, not in any ambiguity on your part, but in failure of comprehension on mine (with passing years sight, hearing, and the mental faculties, decline). You mentioned relatives and friends resident in this city: you may rest assured your lecture-course has added largely to the latter class. You are leaving to rejoin your colleagues in astro-physical research, and we confidently expect to hear of new discoveries surpassing those with which your name is already linked. Perhaps at some future time you may revisit Toronto; in which hope I will say, *au revoir*.

Professor Russell left on March 1 for Pasadena, where he will spend two months at the Mount Wilson Observatory as Research Associate.

It may be interesting to state here that Rev. Alexander Russell, the lecturer's father, was a native of Truro, Nova Scotia. He graduated from Dalhousie University, Halifax, and then studied

theology at Princeton. He was a Presbyterian minister at Oyster Bay, N.Y., for thirty-five years and there Henry Norris was born. Three of Alexander Russell's sisters now live in Toronto.

C. A. CHANT.

MEETINGS OF THE SOCIETY

At Victoria

November 30, 1923.—Mr. Harper in the chair. A regular meeting of the Society was held in the Auditorium of the Girls' Central School at 8 p.m. on the above date.

The following new members were duly elected: Mr. J. Keith Wilson and Miss Wilson.

The Question Box produced the following query: How many hours moonlight is there on an average on December 22 in latitude 85°? This was fully gone into by Mr. Harper.

The address of the evening was then delivered by Dr. J. S. Plaskett on "Recent Astronomical Events in California." Dr. Plaskett in this lecture gave an account of the two recent important astronomical events in California, the total eclipse of the sun on September 10, and the combined meeting of the American Astronomical Society, the Astronomical Society of the Pacific and Section D of the American Association a week later, September 17 to 19. He joined the Yerkes party on Catalina Island but there, as elsewhere in California, the sky was completely clouded and no scientific observations of value were obtained. Only in the interior of Mexico did partial success reward the elaborate preparations for this eclipse. It was very unfortunate and a great loss to science that the many new observations to be attempted at this eclipse, so near the great Mount Wilson Observatory, were prevented by cloudiness.

However, the pleasure and profit of the discussions and examination of the work of the Mt. Wilson Observatory and the great success of the meetings formed a partial compensation for the disappointment. Dr. Plaskett gave a short account of the most important of the papers presented at the meetings, illustrated by slides from snapshots of many of the astronomers present. The meetings of September 17 were held in Los Angeles and consisted of papers on meridian and dynamical astronomy in the morning, with a Symposium on eclipses in the afternoon, with addresses by Dr. Campbell on the Corona, by Dr. Trümpler on the Einstein deflection at the Australian Eclipse, by Prof. S. A. Mitchell on the Flash Spectrum and by Dr. C. E. St. John on the Motions in the Solar Atmosphere. The last paper contained the most important pronouncement of the meeting, Dr. St. John's conclusion, after several years exhaustive work on the subject, that the third astronomical prediction of Einstein, the red-ward displacement of all the lines in the solar spectrum, was also verified. The meetings on Wednesday were held in Pasadena in the morning, in the Observatory Library, where purely astronomical papers were given, and in the afternoon at the Norman Bridge Physical Laboratory, where astronomical papers with a physical bearing were presented. Several important papers were

given at these meetings, but they will be found more fully described in the account in the JOURNAL. The final meeting on the 19th was held on Mt. Wilson in the dome of the 100-inch telescope, a fitting place and a fine ending of memorable meetings. Those attending had a very interesting evening observing various celestial objects with the two great reflectors. Dr. Plaskett concluded by paying a warm tribute to the director and staff of the Mt. Wilson Observatory for their successful efforts at making this a banner meeting of the Society. The lecture was very fully illustrated by lantern slides. A vote of thanks was tendered to Dr. Plaskett and the meeting terminated.

December 11, 1923.—The Annual Meeting was held in the Auditorium of the Girls' Central School on the above date, the President, Mr. W. E. Harper, in the chair.

The following question was answered by Professor Elliott: What, if any, elements have been found in the stars that are not on the earth?

Mr. Harper called attention to *Popular Astronomy* being in the Public Library.

Dr. Plaskett having taken the chair he called upon Mr. Harper to read his paper, entitled "Recent Progress in Astronomy."

In the brief time at his disposal the lecturer gave an account of some discoveries made in astronomy recently, outlining the course of development of each.

The discovery of minor planets has now brought the total to a little over 1000, all of which are small bodies ranging from a few miles to a few hundred miles in diameter.

A theoretical investigation by Jeffreys has given us a new conception of the constitution of the four outer planets. He argues that their low densities, about equal to that of water, suggest that they are cold, solid bodies, their cores being somewhat like ice or composed of materials much less dense than terrestrial rocks.

Investigations at the Lowell and Mount Wilson observatories of the planet Venus reveal the fact that its atmosphere is without water vapour and oxygen, two essentials to the existence of life.

It has been discovered quite recently that the pressure and density in the solar atmosphere are much less than previously concluded. At the Pasadena laboratory certain spectrum lines have been found to be very sensitive to changes of pressure and an examination of these in the solar spectrum indicates a low pressure in the sun's atmosphere, the corresponding density being about 1/100,000 that of our atmosphere at sea level.

Our own atmosphere about 60 miles up has about the same density, a figure which has recently been arrived at by Professor Lindemann of Oxford, who has treated mathematically the observations of meteors made by amateurs the world over. Evidently the temperature at that height is higher than previously believed.

Professor Hale has shown that sun spots are violent tornadoes in the solar atmosphere in which electrified particles are rapidly whirled. Spots usually

occur in pairs connected below the surface as if the letter U were imbedded in the surface. A strong magnetic field surrounds each spot and he used this magnetic field and its effects on spectrum lines to predict where sun spots would soon break out on the solar surface.

The connection between sun spots and aurorae was traced, leading to the knowledge that in a sense we have an aurora every night, as its prominent green spectrum line can be seen and photographed from the general illumination of the night sky. Its wave length has been accurately determined by Babcock, and it shows that it is not due to the gas krypton in the upper air as formerly supposed.

The amount of heat received from the sun has been shown through sensitive instruments to vary as much as five and possibly ten per cent., and these variations studied in connection with temperatures the world over have led to a successful method of weather prediction. It is now in everyday use in Chile and gives great promise of success.

For lack of time the lecturer passed over the recent knowledge accumulated regarding the motions, distances, luminosities and sizes of the stars and brought out some new facts regarding the nebulae. Their various forms, the motions of translation and rotation of the spirals were touched upon. These are the most numerous class and according to Curtis the number is about one million, only one of which is visible to the naked eye. Recently, due to Barnard's work, we have recognized dark as well as bright nebulae which Russell believes to consist of fine particles like dust having diameters from a few millionths to a few hundredths of an inch. The observational work of Hubble has shown that the clouds of nebulosity are excited to luminescence by the stars in their immediate neighbourhood.

Passing reference was made to the substantiation of Einstein's theory by the 1922 eclipse results and also by the small displacements found in the lines in the solar spectrum announced by St. John in September. The lecture was illustrated by suitable slides.

After a hearty vote of thanks had been tendered to Mr. Harper, Professor Elliott took the chair and the officers for the year 1924 were elected. Their names appear in the report of the Annual General Meeting printed in this issue.

F. MOORE, *Secretary.*

At Toronto

November 27, 1923.—A regular meeting of the Society was held in the Physics Building of the University at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

The assistant librarian, Miss E. M. Budd, reported that publications received for the Library in October were: Canada and the Empire, 12; United States, 16; other countries, 22.

Mr. W. E. W. Jackson reported that no spots had been observable on the sun last week, and Mr. A. F. Miller concurred in this observation.

Prof. Chant referred to the occultation of Aldebaran by the Moon on November 23, and Mr. H. F. Balmer stated that they had managed to make three plates of the occultation at the University, but the conditions were not good at the time, owing to occasional cloudiness. Prof. Chant also referred to a booklet recently issued by the Dominion Government, describing the Astrophysical Observatory near Victoria, B.C., and the work of Dr. Plaskett and his staff.

Mr. A. F. Miller spoke of the Pleiades, quoting from an interesting book by Flammarion, and in particular describing their place in history, as well as various early references to them in literature. The Roman poet Ovid gives the fullest mythological account of the Pleiades.

Prof. C. A. Chant described the constellation Orion, illustrating the subject by means of various lantern pictures. The position of this constellation remains favourable for observation during a long period in the winter, as the celestial equator passes through the three stars of the belt of Orion, which are very conspicuous stars, owing to their unique positions with reference to each other. The speaker dwelt upon the nebula in the sword hilt, illustrating it with beautiful photographs.

R. A. Gray, B.A., gave the address of the evening, on "Early Eclipses". An eclipse always made a deep impression upon early peoples, especially an eclipse of the sun, as the solar influence was universally recognized by them as most beneficial; and when this was cut off, as it was in an eclipse of that orb, dread fell upon all. Every primitive nation had its sun-god, that of the Babylonians being named Moloch. As a war was often in progress when an eclipse occurred, the phenomenon in nature soon came to be the sign of some future war, or disaster, and thus arose the study of astrology. Amongst the Chaldeans the wise men made records, from which the Greeks afterward derived their astronomical knowledge. The earliest eclipse on record,—one noted by the Chinese,—occurred on October 22, 2137 B.C. In the writings of Confucius, 36 eclipses are recorded for the fifth, sixth and seventh centuries before Christ.

There are two important advantages derived from studying early eclipses: (1) it enables one to verify the dates of early historical events, and (2), it enables modern astronomers to investigate the motions of the moon. Mr. Gray read accounts of the changes and occurrences during a total eclipse of the sun, one account from Flammarion, another from Johnson's "Historical and Future Eclipses". The striking appearances of everything during the progress of a total solar eclipse led early peoples to regard it as an omen. The speaker made use of numerous lantern slides to illustrate the subject, one of them showing the clay tablet of Babylonia which describes the earliest recorded eclipse amongst the nations other than the Chinese, viz., in the year 1063 B.C. Various references to early eclipses occur in the books of Isaiah and Jeremiah, and in Homer's Odyssey. The most noted of all early eclipses was the eclipse of Thales in 585 B.C., which is described by Herodotus. From their observations on eclipses, the ancients determined the Saros, which has a period of 18 years and 10 or 11 days, according to the number of leap years falling within the period. Mr. Gray

described this feature at some length, and illustrated it with several interesting lantern slides.

December 11, 1923.—A regular meeting was held in the Physics Building of the University at 8 p.m., the President, Mr. W. E. W. Jackson, in the chair.

The Secretary gave a brief summary of the work transacted at the last meeting of the Council on November 30, including the requisite nominations for officers of the Society for the year 1924; and read a letter of acceptance of the office of Honorary President from the Hon. G. H. Ferguson, Premier and Minister of Education for Ontario.

The following were elected members of the Society:

Mr. Z. A. Merfield-Mirfield, University of Melbourne, Australia.

Mr. Jakob Elnes, Camrose, Alberta.

Prof. C. A. Chant drew attention to the reappearance of Venus in the evening sky, and the Secretary mentioned the visibility of the zodiacal light on the morning of November 26, enquiring if the presence of the major planets Jupiter, Saturn and Mars on that side of the sun could have anything to do with the development of the light in that direction. The President and Prof. Chant favoured a negative view.

Mr. A. R. Hassard referred to the recent favourable condition of the atmosphere for viewing the phenomenon called "the old moon in the new moon's arms", and suggested the more frequent use of a good opera glass in viewing the phenomena of the sky. In Taurus, the Pleiades are a fine sight now, as they occupy a central position in an area comparatively devoid of bright stars and afford a good opportunity for viewing with a field glass.

Mr. J. R. Collins pointed out that at the present time it might be possible to see "shooting" stars of the Geminids. He had observed a few on recent nights. The principal displays of the Geminids come upon December 11.

Mr. W. E. W. Jackson reported that no sunspots are visible at this date, and Mr. A. F. Miller concurred in this observation. He had recently tried, with Mr. Jackson and Prof. Chant, to see the companion star of Mira (Omicron Ceti), but without success. Poor seeing conditions prevailed on every occasion.

Mr. Miller added some facts about the various stars in the constellation of Orion, the stars of which he had observed with a small instrument, and had made a few observations. (His remarks on this subject appear on page 60 of the last issue.)

Mr. S. J. McKnight referred to the late Mr. J. C. Hamilton's work on the Pleiades, and other members added to the discussion of Mr. Hamilton's indebtedness to Mr. R. G. Haliburton for the facts in connection with that constellation.

Mr. A. R. Hassard gave an address on the constellation Cassiopeia, which appears to us in the irregular form of the letter 'W', but at the present time, an irregular 'M', as it is inverted. In our latitude it never sinks beneath the horizon. It extends over 35° of declination and from the 23rd to the 3rd hour of right ascension. No star in the constellation is brighter than the third magnitude. In the year 1572, Tycho Brahe discovered a nova in Cassiopeia which had blazed

out so greatly that it was visible at noon-day. It was supposed to have a period of 308 years, and to be the Star of Bethlehem, but at the expiration of that term a few years ago, there was not noticed any nova in that region of the sky. The Milky Way passes through part of Cassiopeia. The speaker advised that everyone should use a star atlas. For his personal use, some years ago, he had copied from Proctor's Star Atlas a star atlas containing 5,000 stars, which he exhibited at this meeting. Some good modern maps of the sky are to be found in the works mentioned in the Preface to the Society's "Handbook" for 1924.

Mr. J. W. Melson gave an address on "The Surveying Camp of the University of Toronto", at Gull Lake in Lutterworth Township, in the north-eastern part of Victoria County. The speaker illustrated his address with many lantern pictures of the camp, views of Gull Lake, the buildings at the camp, the diversions of the students in attendance, making astronomical measurements, etc., all of which added materially to making the address of much interest.

Prof. Chant expressed his appreciation of the large collection of interesting pictures which had been shown, also Mr. Hassard, the President, and others, after which the meeting was adjourned.

At London

December 14, 1923.—The Annual Meeting was held in Room 4, University of Western Ontario, Dr. Kingston presiding. The minutes of the last annual meeting were read and approved. The secretary then read his annual report, showing a membership for the year of 46. During the year eight regular meetings were held. On motion of Mr. Bowen the secretary's report was adopted. The treasurer then read his annual financial statement, showing total receipts for the year of $170.03, total expenditures $136.72, leaving a balance on hand of $33.31. On motion of Miss G. Blackburn and Mrs. Boughner, the treasurer's report was received. Mr. T. Coleridge then reported that the auditors had audited the treasurer's books and found them correct. On motion of Messrs. Coleridge and Middleton the treasurer's statement was adopted. On motion of Mr. W. E. Saunders the secretary was instructed to send a letter to Dean Fox expressing the thanks of the Society for the use of Room 4 as a place of meeting for the year just closed. It was moved by Mr. Bowen, seconded by Mr. McKenzie, and carried, that $5.00 be paid to the caretaker for his services to the Society during the year. On motion of Mr. W. E. Saunders and Rev. R. J. Bowen the officers for 1923 were re-elected for 1924. The names appear in the report of the Annual General Meeting printed in this issue.

It was moved by Miss Grace Blackburn and seconded by Mrs. Middleton that the Council be given authority to give orders for the payment of accounts as they become due. Carried. The meeting adjourned.

E. T. WHITE,
Secretary-Treasurer.

AT MONTREAL

A meeting of the Royal Astronomical Society of Canada, Montreal Centre, was held in the Macdonald Physics Building of McGill University on January 30th.

In the absence of the President, Dr. A. S. Eve presided. Announcement was made of the series of Extension Lectures in Astronomy by Professor Gillson on Wednesday evenings, February 6th, 13th, 20th, 27th, March 5th and 12th. (General fee $3.00, fee for Members of R.A.S.C. $1.50.) A provisional announcement was also made with regard to the regular meetings of the Society for February, March and April.

The lecture of the evening was given by Mr. John Patterson, M.A., of the Dominion Meteorological Office, Toronto, on the "Structure of the Atmosphere."

The gradual development of Meteorology from the lore or superstition of the ancients to the position it holds amongst modern sciences was outlined. Halley was the first to plot the trade winds and monsoons. Curves of equal barometric pressure were shown illustrating the relation of pressure to winds, to temperature and to moisture. Thus the prediction of weather conditions from charts of conditions for several successive days became possible, though subject to uncertainty at all times, due to the erratic motion of the pressure centres, these being sometimes stationary for several days and sometimes moving eastward with a velocity up to 50 miles per hour.

The structure of the atmosphere was described as it has been revealed by observation from aeroplanes and by data from instrument balloons and kites. The highest record is from a balloon which ascended to 23 miles above Italy. A temperature of $-70°$ F. was recorded 15 miles above Canada, and of $-133°$ F. 10 miles above the tropics. The Troposphere is the region of the atmosphere extending up to about 11 km. in which temperature decreases with height and circulation takes place and clouds are formed. Above this region is the Stratosphere where there is no further temperature gradient with height, but only with latitude—the coldest portion of the stratosphere being above the tropics and the warmest above the poles. The twilight limit is 75 km. up; the region for shooting stars 100-180 km.; the region of auroral draperies 100-200 km.; auroral arcs form at 250 km.

The proportional amounts of the various gases which constitute the atmosphere vary with altitude, but nitrogen (and not hydrogen and helium) appears to predominate even in the stratosphere.

The temperature conditions as affecting aeronautical work were discussed and in conclusion the circulation of the atmosphere was described as the greatest transportation system, accomplishing the stupendous task of shifting a million million tons of air in two or three days from one region 1000 miles in diameter to another region, at the same time carrying perhaps 1000 million tons of water to deposit them upon the earth as rain or snow. The source of all this energy is the sun.

A hearty vote of thanks was tendered to the speaker by Dr. Eve on behalf of the audience.

A. V. DOUGLAS,
Assistant Recorder.

The Royal Astronomical Society of Canada

(OFFICERS FOR 1924—REVISED TO MARCH 1ST, 1924)

Honorary President—HON. G. H. FERGUSON, K.C., B.A., LL.D., Minister of Education for Ontario.
President—R. M. STEWART, M.A., Ottawa.
First Vice-President—WM. BRUCE, J.P., Hamilton.
Second Vice-President—A. F. HUNTER, M.A., Toronto.
General Secretary—F. T. STANFORD, Toronto.
General Treasurer—H. W. BARKER, Toronto.
Recorder—H. F. BALMER, B.A.
Librarian—PROF. C. A. CHANT.
Curator—ROBERT S. DUNCAN.

Council—MGR. C. P. CHOQUETTE, M.A., LIC.SCS., Montreal; J. B. FRASER, M.D., Toronto; R. A. GRAY, B.A., Toronto; A. R. HASSARD, B.C.L., Toronto; J. H. HORNING, M.A., Toronto; PROF. JOHN MATHESON, M.A., Kingston; SIR JOSEPH POPE, K.C.M.G., Ottawa; JOHN SATTERLY, M.A., D.Sc., Toronto; DR. W. M. WUNDER, Toronto; and Past Presidents: JOHN A. PATERSON, M.A., K.C.; SIR FREDERIC STUPART, F.R.S.C.; A. T. DELURY, M.A.; LOUIS B. STEWART, D.T.S.; ALBERT D. WATSON, M.D.; ALLAN F. MILLER; J. S. PLASKETT, B.A., D.Sc., F.R.S.; J. R. COLLINS; W. E. W. JACKSON, M.A.; and the Presiding Officer of each Centre as follows: R. J. MCDIARMID, Ph.D., Ottawa; REV. FATHER T. W. MORTON, B.Sc., Winnipeg; W. E. HARPER, M.A., Victoria, B.C.; JUSTICE E. E. HOWARD, Montreal; H. R. KINGSTON, M.A., Ph.D., London, Ont., and the Officers as above.

OTTAWA CENTRE

President—R. J. MCDIARMID, Ph.D. *Vice-President*—C. R. COUTLEE, C.E.
Secretary—A. H. MILLER, M.A. *Treasurer*—W. S. MCCLENAHAN, B.A.

Council—T. L. TANTON, Ph.D.; E. A. HODGSON, M.A.; THOMAS DONOHER, and Past Presidents: R. M. STEWART, M.A.; F. A. MCDIARMID, M.A.; J. J. MCARTHUR, D.L.S., and R. E. DELURY, Ph.D.

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE, M.A., LIC.SCS.
President—HON. JUSTICE E. EDWIN HOWARD.
1st Vice-President—MR. H. E. S. ASBURY.
2nd Vice-President—PROF. A. H. S. GILLSON.
Secretary-Treasurer—MR. A. W. STRONG.
Recorder—REV. W. T. B. CROMBIE, M.A., B.D.
Assistant Recorder—MISS A. V. DOUGLAS.

Council—PROF. A. S. EVE, D.Sc., C.B.E.; MR. GEO. SAMPLE; MR. JULIAN C. SMITH; MR. E. W. PASK; MISS M. H. ELLICOTT.

LONDON CENTRE

President—H. R. KINGSTON, M.A., Ph.D.
Vice-President—MISS GRACE BLACKBURN.
Secretary-Treasurer—E. T. WHITE, B.A., D.Paed.

Council—REV. R. J. BOWEN, F.R.G.S.; MRS. S. R. MOORE; H. B. HUNTER; J. C. MIDDLETON; W. A. MCKENZIE.

WINNIPEG CENTRE

President—REV. T. W. MORTON, B.Sc.
Vice-President—MRS. E. L. TAYLOR.
Curator—DR. L. A. H. WARREN.
Secretary-Treasurer—MR. H. B. ALLAN.

Council—DR. N. B. MACLEAN; MRS. S. C. NORRIS; MR. D. P. MORSE, C.E.; DR. N. R. WILSON; MR. J. H. KOLB; MR. CECIL ROY.

VICTORIA CENTRE

Honorary President—DR. J. S. PLASKETT, F.R.S.
President—MR. J. DUFF.
Vice-President—MR. F. C. GREEN.
Treasurer—MR. J. P. HIBBEN.
Secretary—MR. F. MOORE.

Executive Committee—MESSRS. P. H. ELLIOTT; H. CAMERON; R. G. MILLER; W. H. CHRISTIE.

Auditor—MR. H. H. PLASKETT.